ESIP Federation Interoperability Outreach Package

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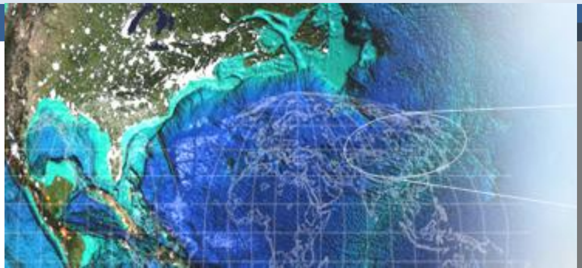

Acknowledgements

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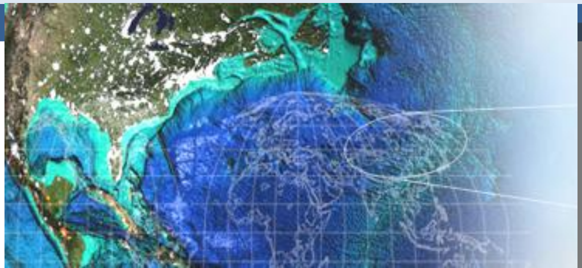
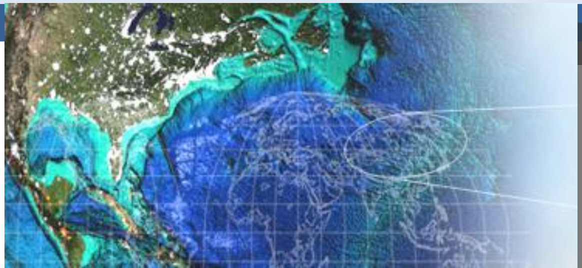
Background



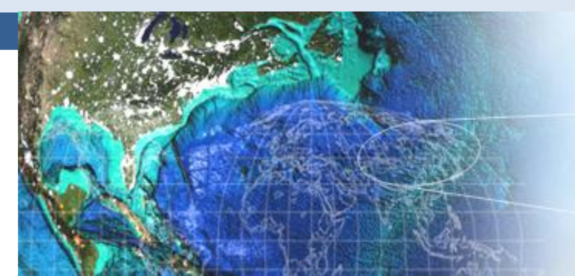
About the ESIP and IT&I Cluster

- The ESIP Federation is a consortium of more than 110 organizations that collect, interpret, and develop applications for Earth observation information.
- Partners include NASA and NOAA as strategic funding partners (Type IV), USGS data centers, and research universities, as well as many other organizations involved in Earth science.
- ESIP's Information Technology and Interoperability cluster was created, in part, "to ensure that data, information and services can be readily discovered, exchanged and integrated through the use of interoperability standards and protocols."



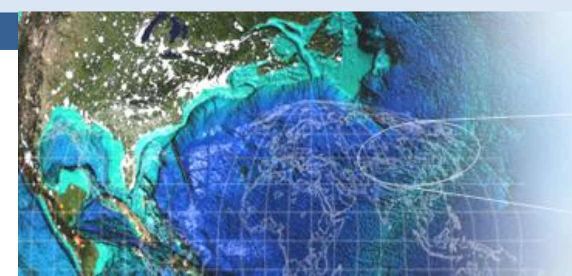
Outreach Goal

The ESIP Federation initiative coupled with community standards, such as those of the Open Geospatial Consortium (OGC) and existing legacy systems, will allow different scientific communities to work together to achieve a bigger vision.



About Interoperability

- “The capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units.” According to ISO/IEC 2382-01, Information Technology Vocabulary, Fundamental Terms
- The IEEE (Institute of Electrical and Electronics Engineers) defines interoperability as: “the ability of two or more systems or components to exchange information and to use the information that has been exchanged.”



Types of Interoperability

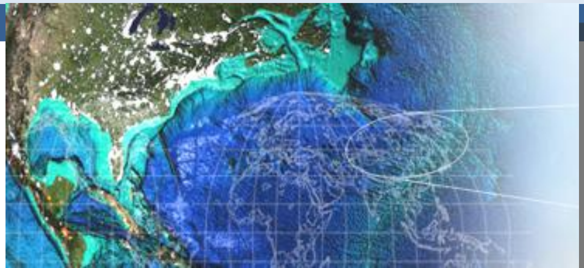
Syntactic interoperability

"If two or more systems are capable of communicating and exchanging data, they are exhibiting syntactic interoperability. Specified data formats, communication protocols and the like are fundamental. In general, XML or SQL standards provide syntactic interoperability. This is also true for lower-level data formats, such as ensuring alphabetical characters are stored in ASCII format in both of the communicating systems."

Syntactical interoperability is a necessary condition for further interoperability.

Semantic interoperability

"Beyond the ability of two or more computer systems to exchange information, semantic interoperability is the ability to automatically interpret the information exchanged meaningfully and accurately in order to produce useful results as defined by the end users of both systems. To achieve semantic interoperability, both sides must defer to a common information exchange reference model. The content of the information exchange requests are unambiguously defined: what is sent is the same as what is understood."



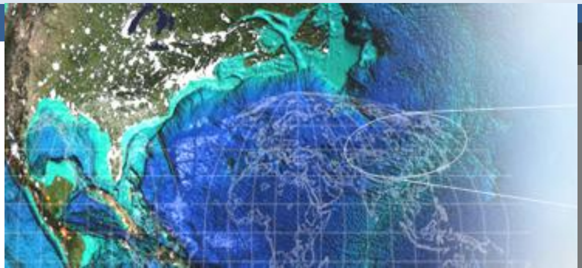
Approaches to Interoperability

There are two approaches:

- Build a new system which may incur higher cost
- Utilize the pre-existing legacy system and bring it up to speed

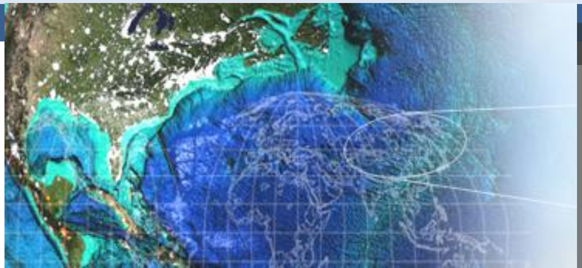
Regardless of which path is selected, both require:

- A service-oriented approach that underlies much of today's World Wide Web
  - New systems shall use a service-oriented approach to making their data available to distributed communities of scientists
- Transaction-oriented and conceptual aspects of Web 2.0

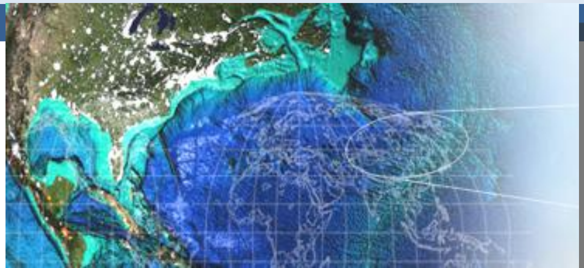


Interoperability Standards

- Open Geospatial Consortium (OGC) Standards
- ESIP Federation Open Search
- Open-source Project for a Network Data Access Protocol (OPeNDAP)
- Metadata
- File Formats



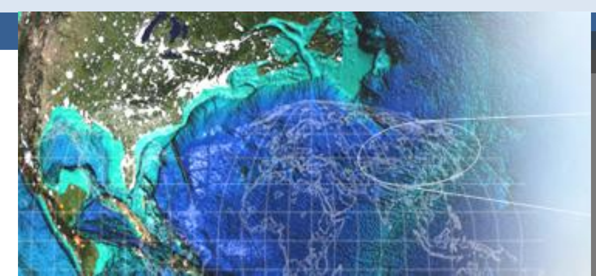
Interoperability by Functionality



Interoperability by Functionality (1/2)

This Outreach package focuses on interoperability based on three main areas of functionality:

- Data Access
- Catalog Search and Discovery
- Usage and File Formats



Interoperability by Functionality (2/2)

Data Access

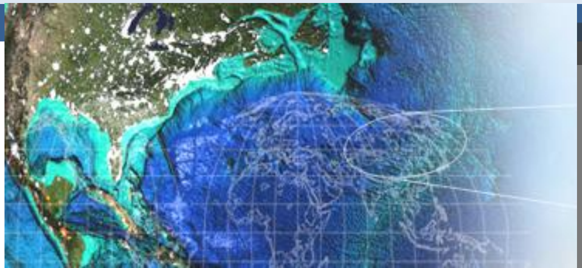
- OGC Standards
  - WMS, WCS, WFS
  - SWE, SSW, GSW
- OPeNDAP

Catalog Search And Discovery

- ESIP Open Search
- CS-W
- ebRIM
- GEOSS Search & Discovery
- Federated Search

Usage and File Formats

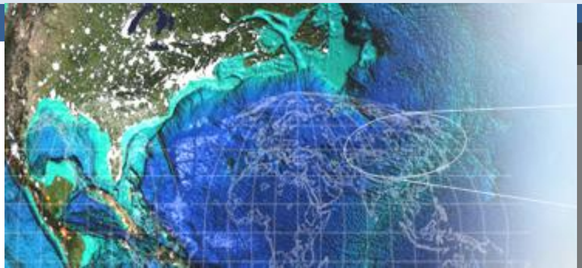
- Meta Data File Formats
  - FDGC
  - NetCDF and CF
  - ISO 19115 and 19119
  - NASA ECS and GCMD DIF



OGC Participants/Communities

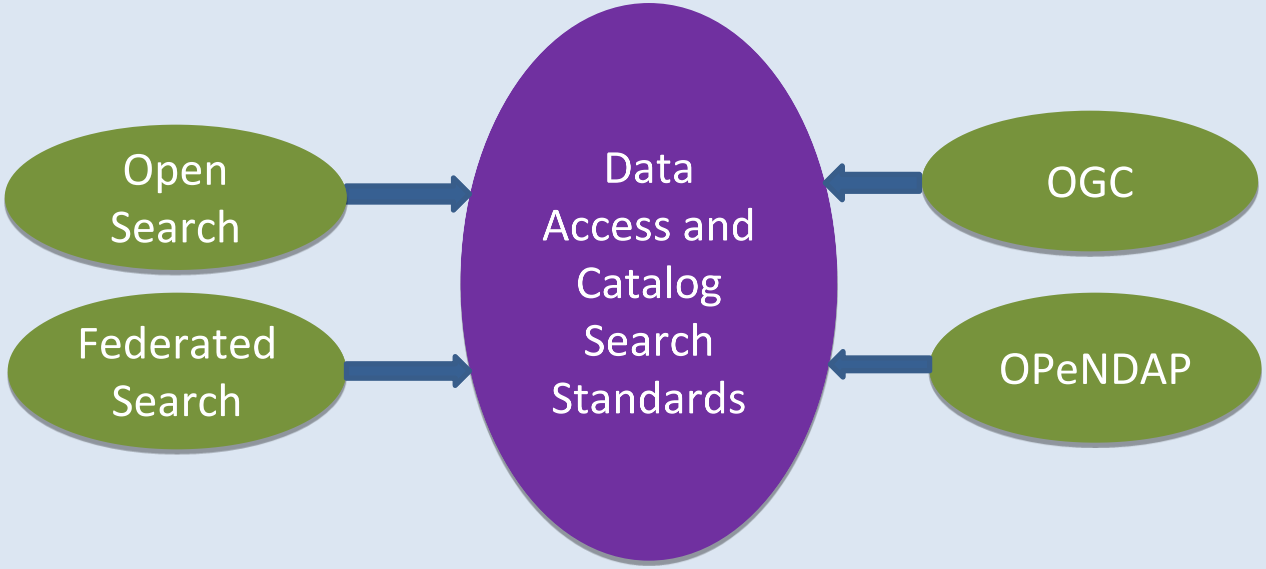
There are three primary groups of participants:

1. Data providers who should be able to download an API to implement OGC web services to distribute their data.
2. The community of users who can utilize a web-based visualization tool or client tool that is capable of communicating with data providers in a form such as REST, SOAP, or XML.
3. Developers who implement, test, and integrate these systems/software and provide them to the user community. This developer community is formed by a group of experts in software engineering, standards, and database managers.



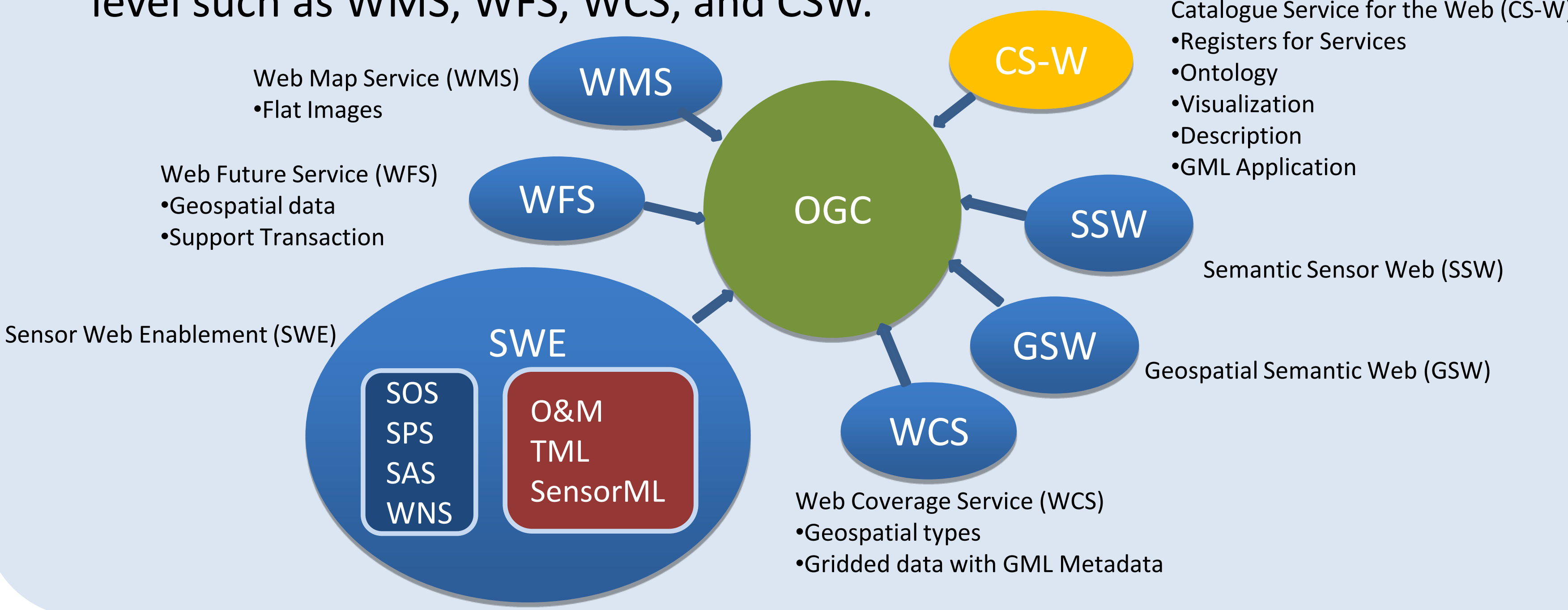
Interoperability Standards

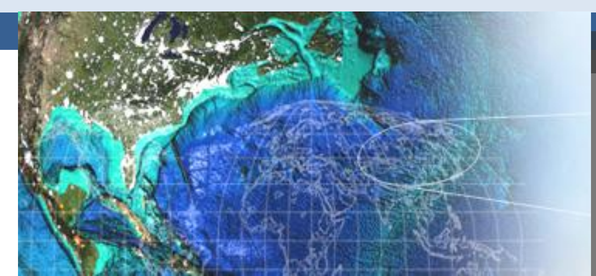
Interoperability standards include ones developed by the Open Geospatial Consortium (OGC), Federated Search, and OPeNDAP.



OGC Standards

The Open Geospatial Consortium (OGC), via their standards process, has developed protocol standards implemented operationally at various level such as WMS, WFS, WCS, and CSW.





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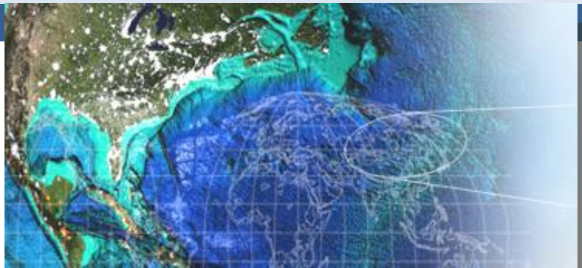
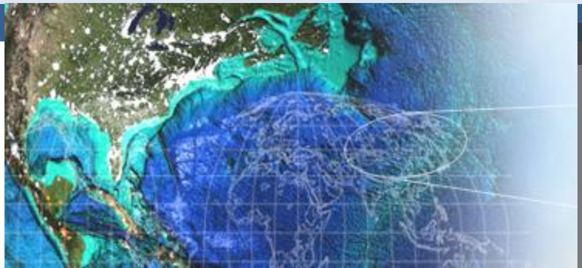
Data Access – OGC

Open Geospatial Consortium



Some OGC Standards

- Web Map Service (WMS)
- Web Feature Service (WFS)
- Web Coverage Service (WCS)
- Sensor Web Enablement (SWE)
- Catalog Services - Web (CS-W)
- Geospatial Semantic Web (GSW)
- Semantic Sensor Web (SSW)

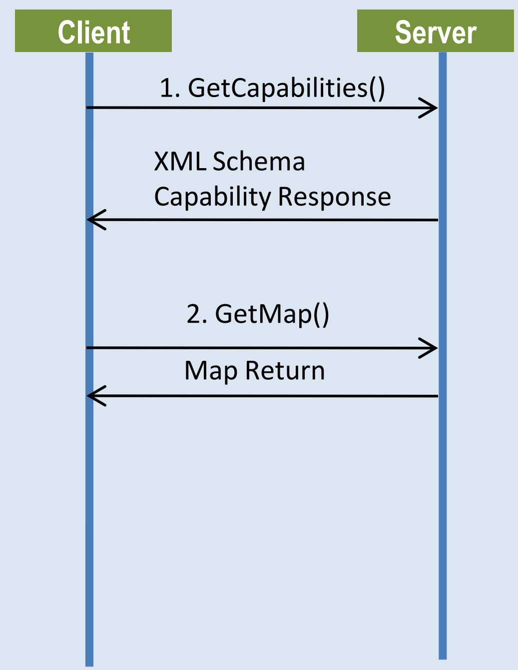


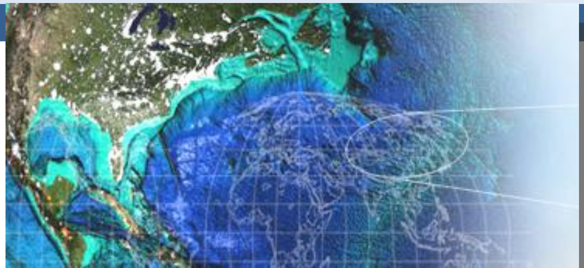
Web Map Service (WMS) – Maps

WMS Features

- OGC WMS standards serve visualizations of geographical data in “flat” map-like layered images.
- HTTP queries a WMS server and returns pre-rendered images from different sources.
- The returned images from different sources can be layered on top of each other.

Client sends a request to the server using HTTP





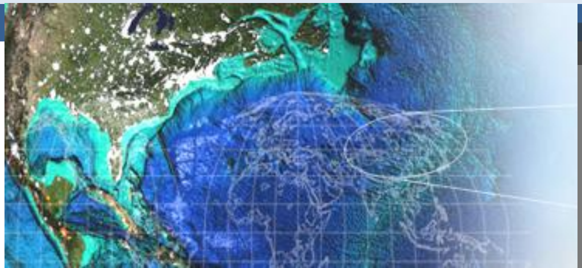
WMS Examples (1/3)

- The following links are two XML examples for GetCapabilities Request:
- Northern Hemisphere: http://nsidc.org/cgi-bin/atlas_north?service=WMS&request=GetCapabilities&version=1.1.1
- Southern Hemisphere: http://nsidc.org/cgi-bin/atlas_south?service=WMS&request=GetCapabilities&version=1.1.1

WMS Examples (2/3)

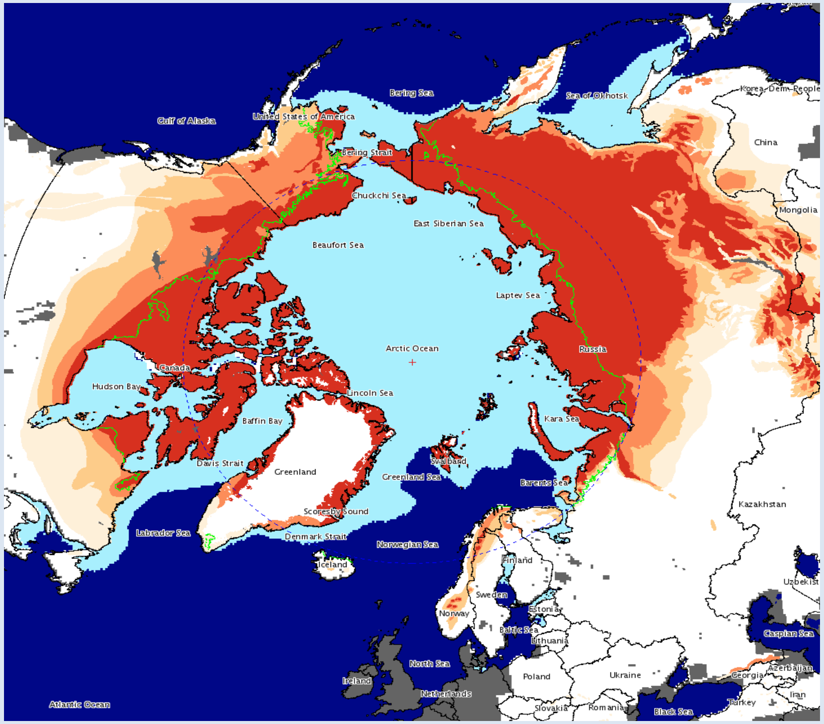
GetMap Northern Hemisphere request using the known parameters from GetCapabilities:

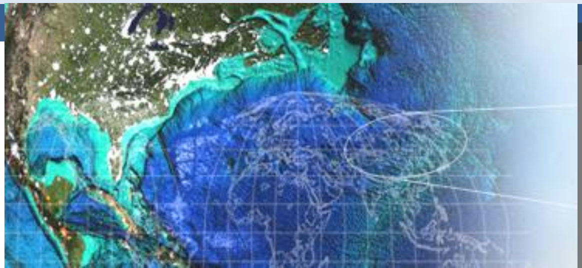
http://nsidc.org/cgi-bin/atlas_north?
service=WMS&
version =1.1.1&
request =GetMap&
srs=EPSG:32661&
format=image/gif&
width=1000&
height=1000&
bbox=-2700000,-2700000,6700000,6700000&
layers=sea_ice_extent_01,land,snow_extent_01,permafrost_extent,country_borders,treeline,north_pole_geographic,arctic_circle,country_labels,geographic_features_sea



WMS Examples (3/3)

GetMap Response from Server:





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Web Feature Service (WFS) – Features

WFS Features

Publishes feature-level geospatial data to the web and supports INSERT, UPDATE, DELETE, LOCK, QUERY, and DISCOVERY operations on these data using HTTP

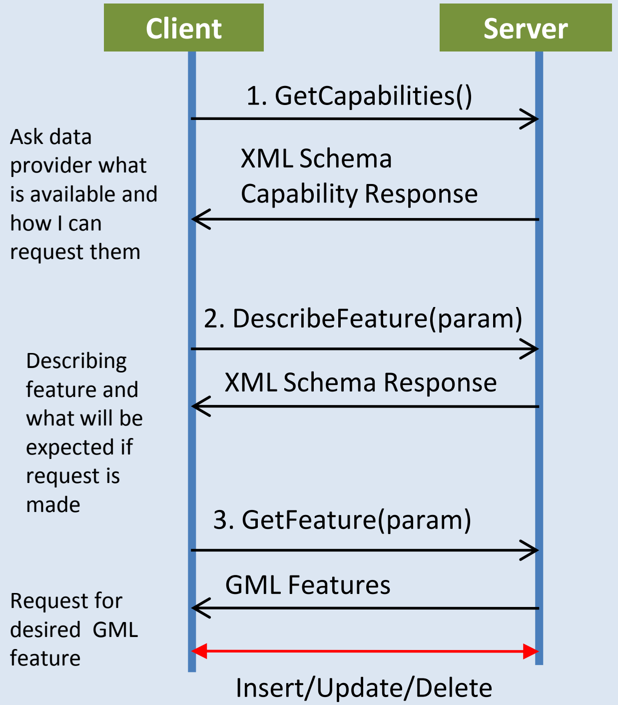
WFS Provides three main Requests:

- GetCapabilities: Describes its which feature types it can service and what operations are supported on each feature type.
- DescribeFeatureType: Describes the structure of any feature type it can service
- GetFeature: Allows retrieval of feature instances based on client specified request to constrain the query spatially and non-spatially.

WFS Optional Requests:

- GetGmlObject: Provides retrieval of element instances by traversing XLinks that refer to their XML IDs.
- Transaction : Allows create, update, and delete operations on geographic features
- LockFeature: Provides lock request on one or more instances of a feature type for the duration of a transaction to ensure support of serializable transactions

Client sends a request to the server using HTTP



WFS Benefits

- Instead of returning an image as WMS does, WFS provides detailed information about specific geospatial features of the underlying data, at geometry and attribute levels.
- Unlike the WMS getFeatureInfo request that only returns information about the feature, WFS provides the geometry itself.
- Whereas WMS offers imaging services, WFS provides geographical features as the “source code” behind the map.
- WFS has optional features that allow inserting and modifying geospatial objects such as weather observation readings.

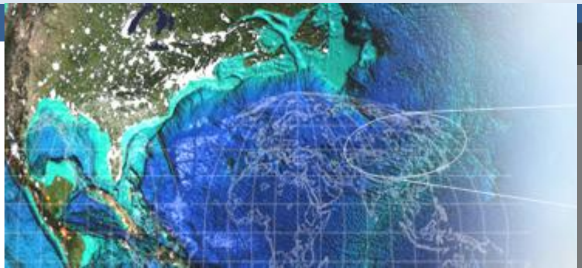
WFS Examples (1/3)

- The following links are two examples for GetCapabilities Request:
- Northern Hemisphere: http://nsidc.org/cgi-bin/atlas_north?service=WFS&request=GetCapabilities&version=1.1.0
- Southern Hemisphere: http://nsidc.org/cgi-bin/atlas_south?service=WFS&request=GetCapabilities&version=1.1.0

WFS Examples (2/3)

GetFeature Request: Elevation contours for the Greenland ice sheet:

http://nsidc.org/cgi-bin/atlas_north?service=WFS&version=1.1.0&request=GetFeature&typename=greenland_elevation_contours



WFS Examples (3/3)

WFS GetFeature XML Response from Server:


```
<wfs:FeatureCollection xsi:schemaLocation="http://mapserver.gis.umn.edu/mapserver http://nsidc.org/cgi-bin/atlas_north?SERVICE=WFS&VERSION=1.1.0&REQUEST=DescribeFeatureType&TYPENAME=greenland_elevation_contours&OUTPUTFORMAT=text/xml;
subtype=gml/3.1.1  http://www.opengis.net/wfs http://schemas.opengis.net/wfs/1.1.0/wfs.xsd">
<gml:boundedBy><gml:Envelope srsName="EPSG:32661">
<gml:lowerCorner>-406699.951843 -456661.863393</gml:lowerCorner>
<gml:upperCorner>1677349.428068 1589388.039689</gml:upperCorner>
</gml:Envelope>
</gml:boundedBy>
<gml:featureMember>
<ms:greenland_elevation_contours><gml:boundedBy>
<gml:Envelope srsName="EPSG:32661“>
<gml:lowerCorner>-327189.501776 -456661.863393</gml:lowerCorner>
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</gml:featureMember>
</wfs:FeatureCollection>
```
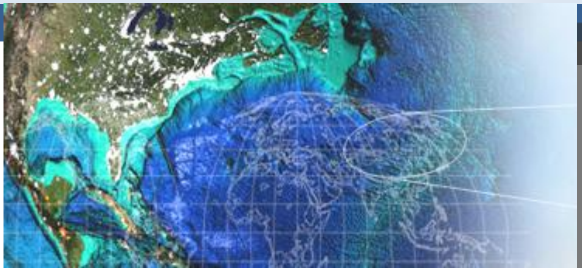


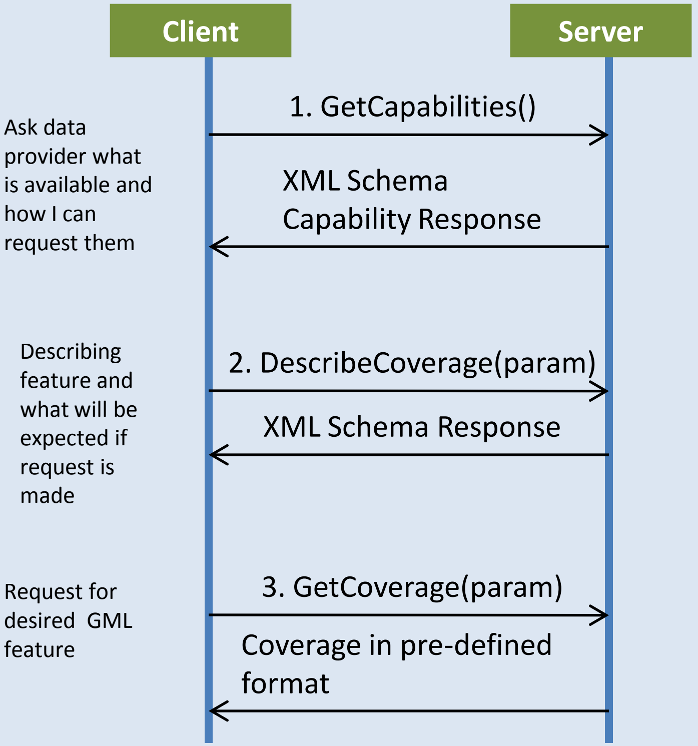


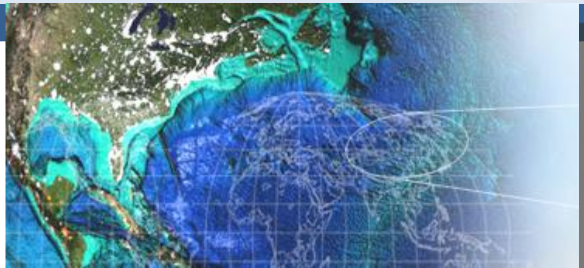
Web Coverage Service (WCS) – Gridded data

WCS Features

- **Gridded data with GML metadata**
- Enables interoperable access to detailed and rich geospatial data as “coverages”
- Supports Binary files: GeoTiff, HDF-EOS, CF-NetCDF, JPEG
- **Provides three main Requests:**
  - GetCapabilities: Retrieves a list of the server’s ata, available Services, WCS operations, and parameters
  - DescribeCoverage: Retrieves an XML document that fully describes the requested coverages
  - GetCoverage: Returns a coverage in a well-known format with several extensions to support the retrieval of coverages

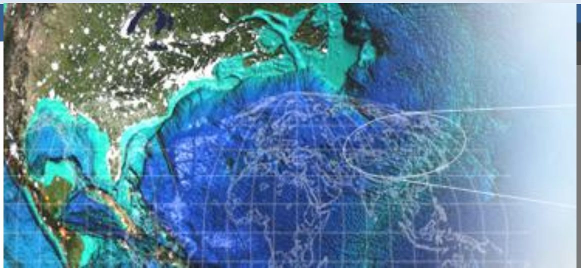
Client sends a request to the server using HTTP





WCS Benefits

- Like WMS, the WCS standard returns similar formats
- In addition, WCS is capable of providing:
  - valuable metadata and more formats
  - multi-valued coverages
  - more precise queries against multi-dimensional back-end formats
  - raster data in form of "source code" with detailed descriptions of the map (unlike WMS raw static image)
  - coverages that relate a multi-dimensional spatio-temporal domain to a range of properties (unlike WFS which returns discrete geospatial features)



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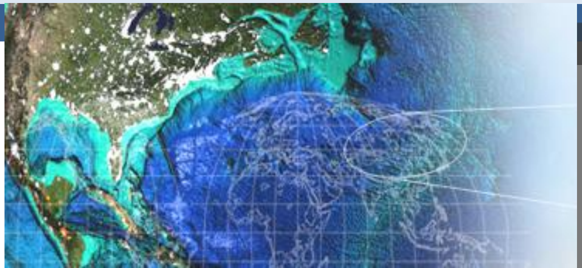
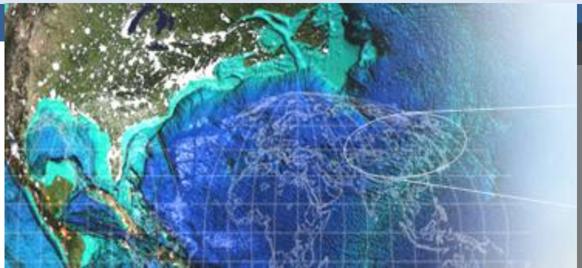


WCS Examples (2/3)

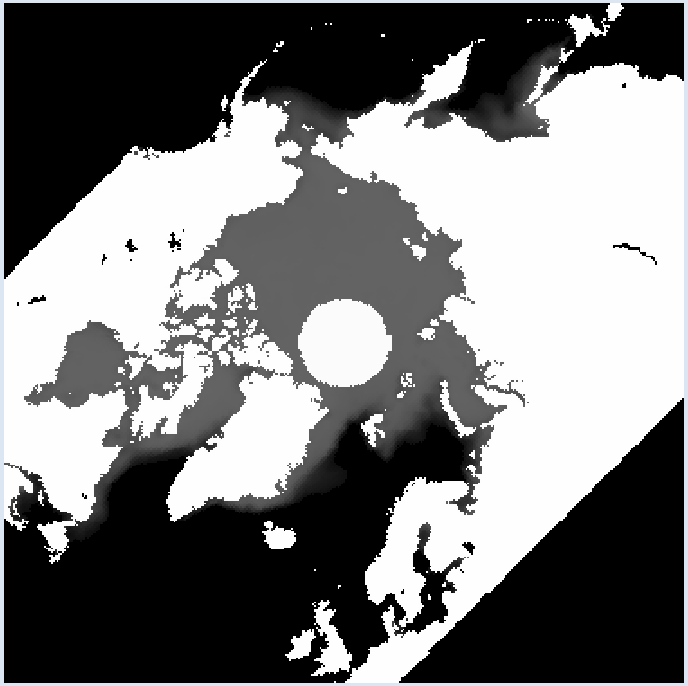
GetCoverage : After requesting GetCapabilities and DescribeCoverage, the WCS Client can place a GetCoverage Request. The below is a GetCoverage REST request for A GeoTIFF of sea ice concentration at 25-km resolution in a polar stereographic projection focused on the Arctic (138 KB):

http://nsidc.org/cgi-bin/atlas_north?
service=WCS&
version=1.1.1&
request =GetCoverage&
crs=EPSG:32661&
format=GeoTIFF&
resx=25000&
resy=25000&
bbox=-2700000,-2700000,6700000,6700000&
coverage=sea_ice_concentration_01



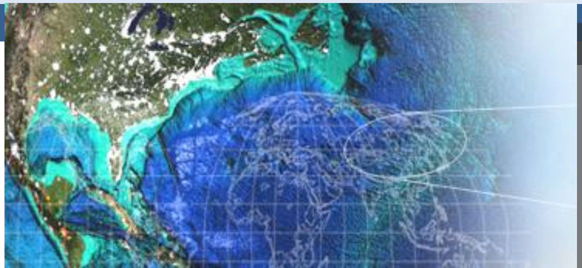
WMS Examples (3/3)

GetCoverage Response from Server:



Sensor Web Enablement (SWE)

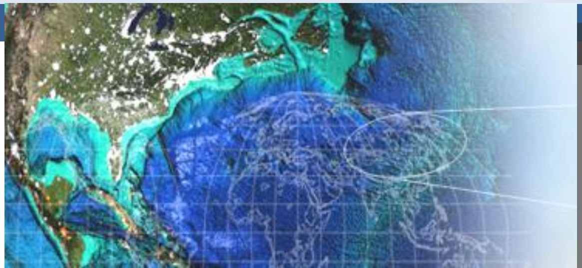
- Enables interoperability among different sensor types, different systems, and different groups:
  - Remote sensor vs. in-situ
  - Emergency system, utility, defense, science, and intelligence
  - Government vs. commercial
- Supports any sensor
- Supports semantic web on-line dictionary and ontology
- Task sensors
- Subscribe to sensor published alerts



SWE Goals

OGC SWE's goal is to discover:

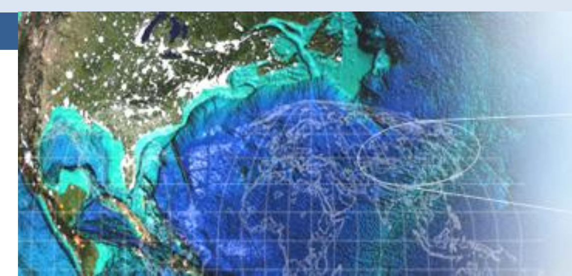
- Sensor systems
- Observations and processes
- Sensor capabilities and quality of measurements
- Sensor parameters that allow software to process and geolocate observations
- Methods to retrieve real-time or time series observations and coverages



Sensor Web Enablement Models

SWE is a Service Oriented Architecture (SOA) open standard providing:

- Four standard web services interface models
  - Sensor Observation Service (SOS)
  - Sensor Alert Service (SAS)
  - Sensor Planning Service (SPS)
  - Web Notification Service (WNS)
- Three XML encoding information models
  - Sensor Model Language (SensorML)
  - Observations and Measurements (O&M)
  - Transducer Markup Language (TML)



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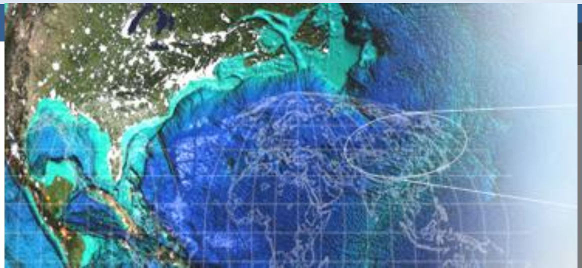
SWE Standard Web Services Interface Models

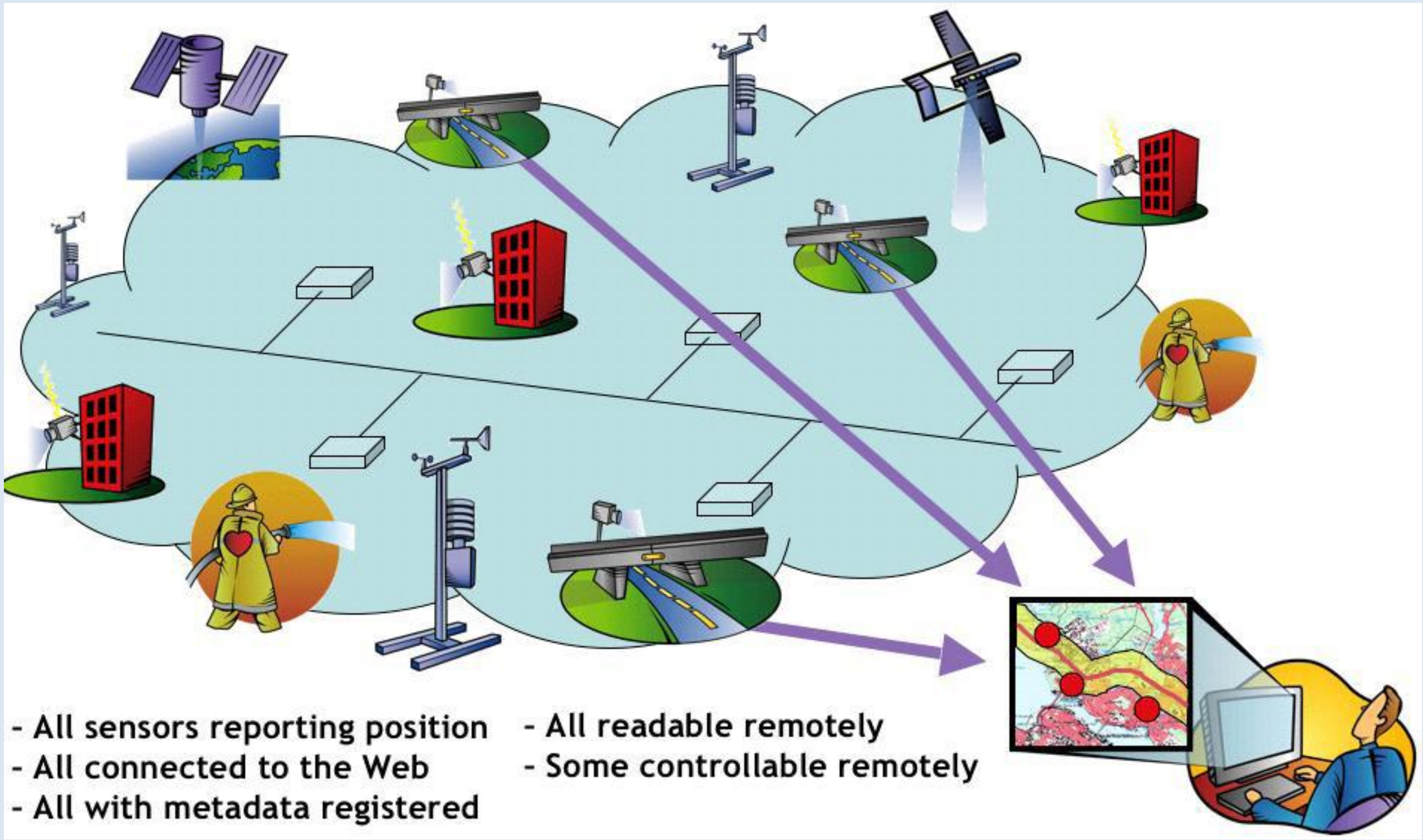
- Sensor Observation Service (SOS)
  - Fetch observations from a sensor or collection of sensors.
- Sensor Alert Service (SAS)
  - Publishing and subscribing to alerts from sensors
- Sensor Planning Service (SPS)
  - Requesting user-driven acquisitions and observations
- Web Notification Service (WNS)
  - Asynchronous delivery of messages or alerts from SAS and SPS web services and other elements of service workflows.



SWE XML Encoding Information Models

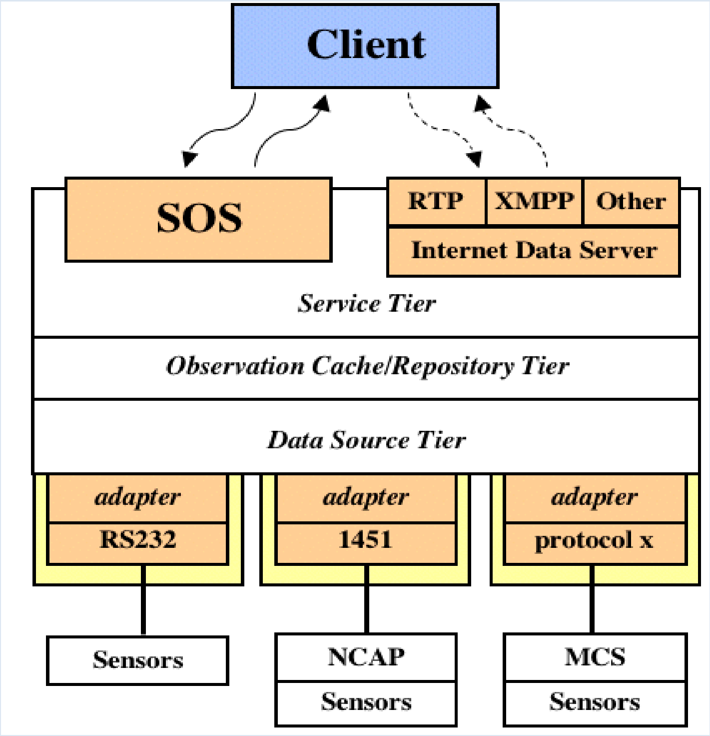
- Sensor Model Language (SensorML)
  - Standard models and XML Schema for describing sensors systems and processes.
- Observations and Measurements (O&M)
  - Standard models and XML Schema for encoding observations and measurements from a sensor, both archived and real-time.
- Transducer Markup Language (TML)
  - The conceptual model and XML Schema for describing transducers and supporting real-time streaming of data to and from sensor systems.

SWE Vision

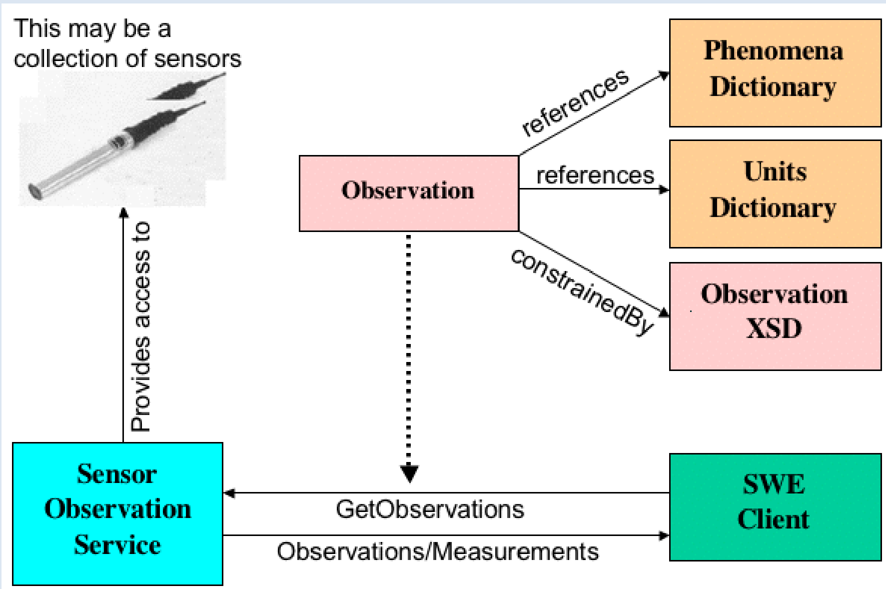

- All sensors reporting position
- All connected to the Web
- All with metadata registered
- All readable remotely
- Some controllable remotely

SWE Interface Standard

To avoid the requirement to make unique smart transducers for each network on the market, transducer manufacturers have supported the development of a universally accepted transducer interface standard, the IEEE 1451 standard.

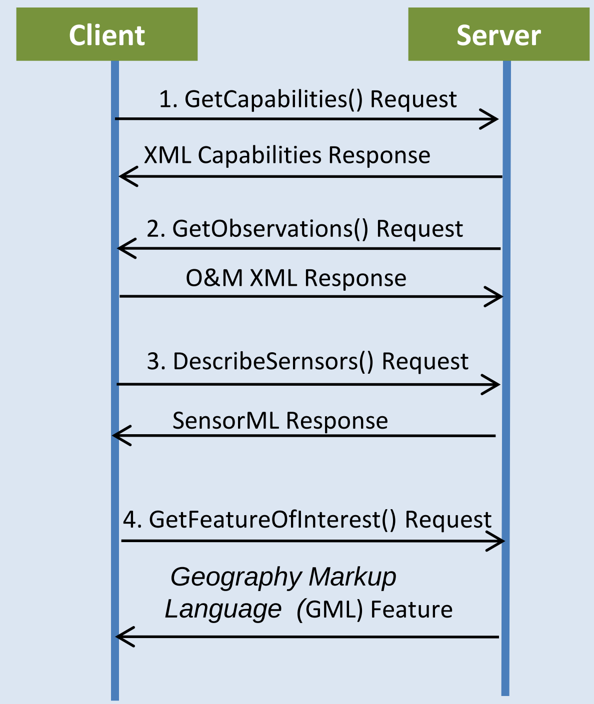


SOS Concept



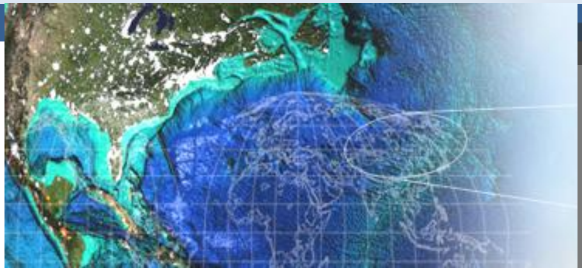
Sensor Observation Service Concept

Client sends a request to the server using HTTP



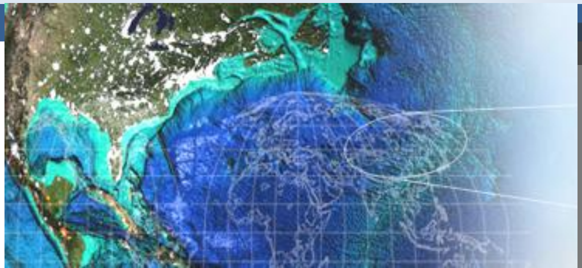
SensorML (1/4)

The OpenGIS® Sensor Model Language Encoding Standard (SensorML) specifies models and XML encoding that provide a framework within which the geometric, dynamic, and observational characteristics of sensors and sensor systems can be defined.



SensorML (2/4)

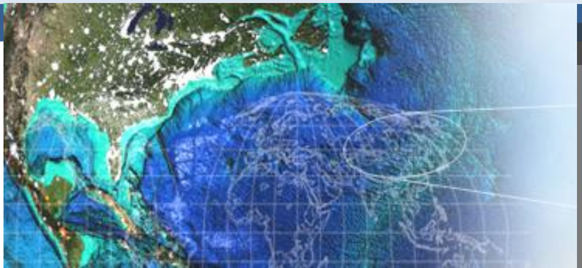
The Objective of SensorML is to provide a complete description of an instrument’s capabilities and give the information needed to process and geolocate the measured data.



SensorML (3/4)

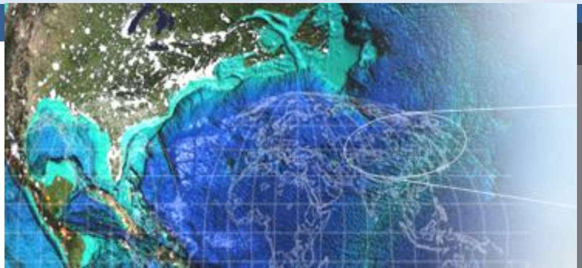
SensorML information includes:

- Sensor name, type, and identification numbers
- Temporal, legal, or classification constraints
- A reference to the platform description
- The sensor's coordinate reference system definition
- The sensor's location
- The response characteristics and information for geolocating samples
- The sensor operator and tasking services
- Textual metadata and history of the sensor
- Textual metadata and history of the sensor description document



SensorML (4/4)

- By describing sensors using SensorML, anyone can put sensors or sensor data online for others to find and use.
- By automating the reading of metadata, SensorML will enable the development of software tools that automatically co-register different kinds of data with little human intervention.
- SensorML makes sensors become more intelligent and autonomous by assisting in onboard processing of data and communications among multiple sensors.

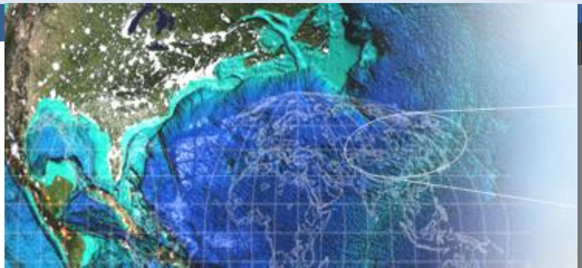


Data Access – OPeNDAP

Open-source Project for a Network Data Access Protocol

OPeNDAP Data Access System

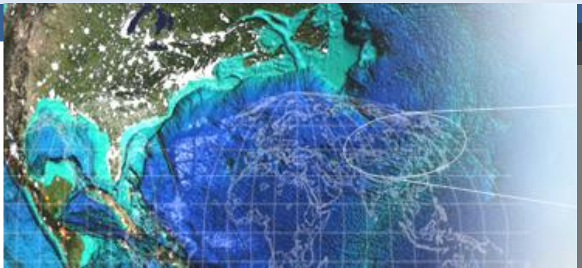
- Open-source Project for a Network Data Access Protocol (OPeNDAP) is a data transport and protocol, based on HTTP, used by Earth Scientists.
- OPeNDAP specifies how to request a subset of a large dataset .
- It also specifies the over-the-network format for the response.
- The simplicity, flexibility, and efficiency of the protocol have led to its wide usage in the oceanographic and other scientific communities.
- There are many DAP compatible servers such as Hyrax, THREDDS, PyDAP, and ERDDAP.
- OPeNDAP servers manage large amounts of remotely sensed and model data, typically in grid formats such as NetCDF, GRIB, and HDF.



OPeNDAP Response Types

OPeNDAP provides three basic data types, and Request to Client OPeNDAP will result in following three different requests for data to OPeNDAP Server:

- Request for the Data Descriptor Structure (DDS): is a data structure to describe datasets and subsets of those datasets – Shape of Data
  - Syntactic Metadata - Rigid
- Request for the Data Attribute Structure (DAS): is a set of name-value pairs used to describe the data in a particular dataset
  - Semantic Metadata - Flexible
- Request for actual Data (DODS): is data structure used by the DODS software to describe datasets



OPeNDAP Client Server Architecture (1/3)

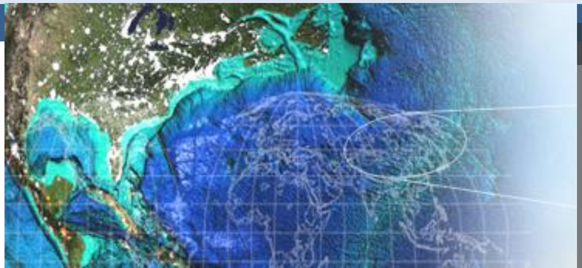
OPeNDAP Servers:

- CODAR
- netCDF
- HDF4/5
- Matlab
- DSP
- Tables (JGOFS)
- SQL (JDBC)
- FITS
- CDF

OPeNDAP Client Server Architecture (2/3)

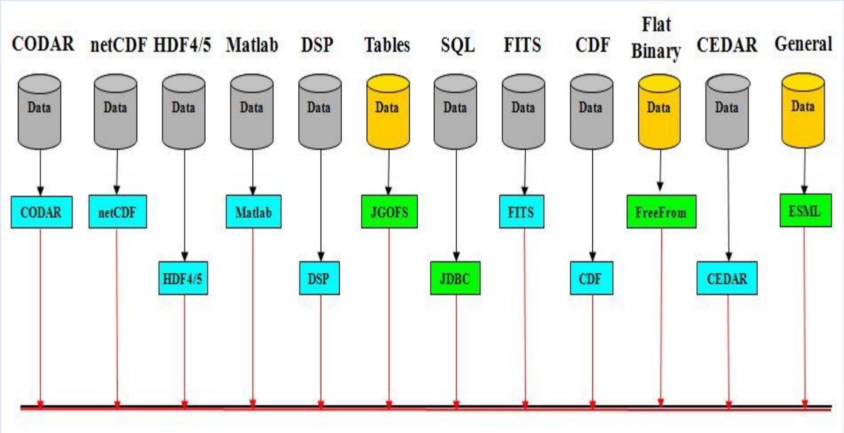
OPeNDAP Clients :

- Ferret and GrADS (netCDF C)
- IDV, VisAD, and ncBrowse (netCDF Java)
- Matlab
- IDL
- Access
- Excel

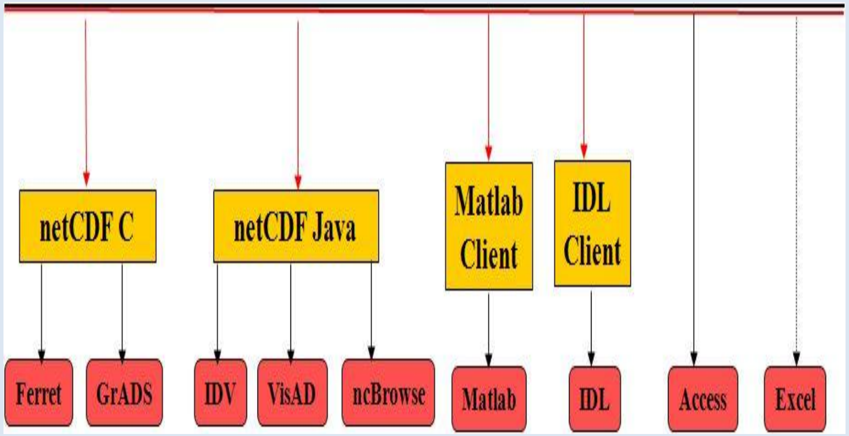


OPeNDAP Client Server Architecture (3/3)

- OPeNDAP Servers

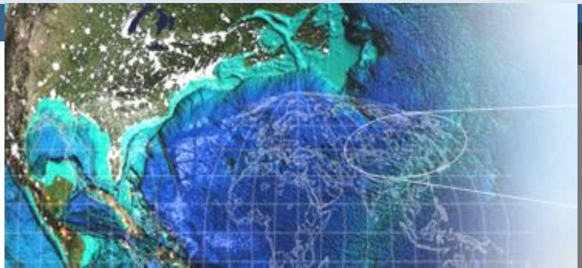


- OPeNDAP Clients



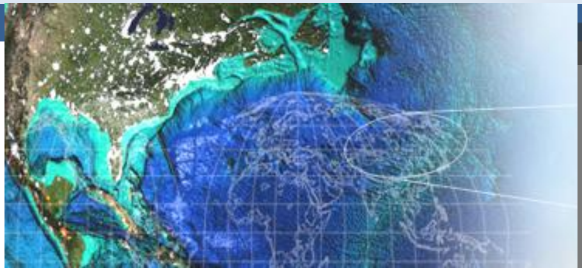
OPeNDAP Service at GSFC

- Currently, the GES DISC offers the datasets listed at http://disc.gsfc.nasa.gov/services/opendap/ through OPeNDAP.
- For example, AIRS data are made available through http://disc.sci.gsfc.nasa.gov/gesNews/opendap_AIRS_data_access



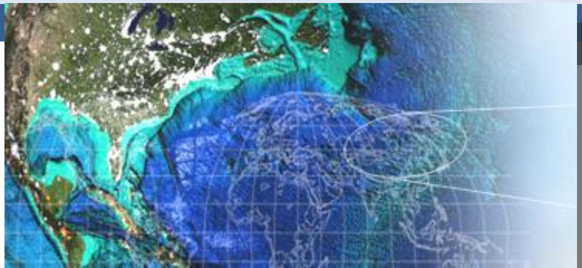
Uses of OPeNDAP

- OPeNDAP can be used to:
  - Make netCDF data files available over the Internet
  - Adapt existing software that use the netCDF API to read data served by an OPeNDAP data server
- In general, any program that uses netCDF can become a client in the OPeNDAP client-sever system.

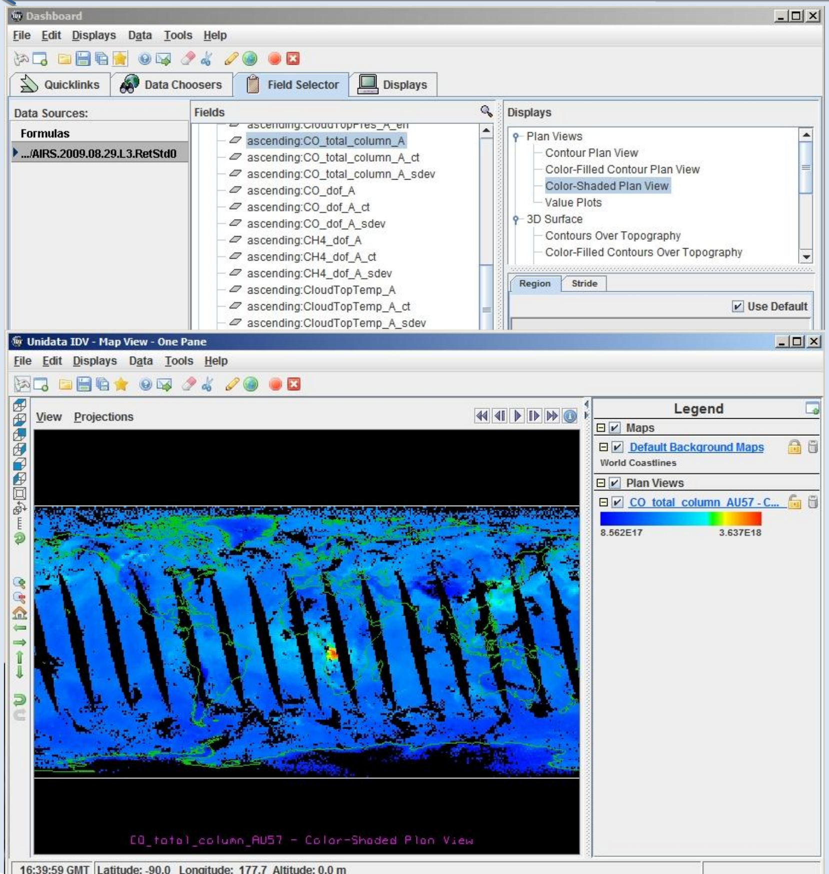


OPeNDAP Support of IDV, GrADS, and Panoply

- There are a variety of tools and file formats used with Earth science data, including IDV, GrADS, and Panoply.
- In general, IDV and Panoply have the easiest learning curves while GrADS is somewhat harder.
- OPeNDAP allows for remote access of data at a sub-file level, making the data easier to use.



IDV Example



Carbon Monoxide Plume from California wildfires, seen in AIRS Daily Level 3 (AIRX3STD) on 29 Aug 2009: http://acdisc.gsfc.nasa.gov/opendap/Aqua_AIRS_Level3/AIRX3STD.005/2009/AIRS.2009.08.29.L3.RetStd001.v5.2.2.0.G09243131454.hdf

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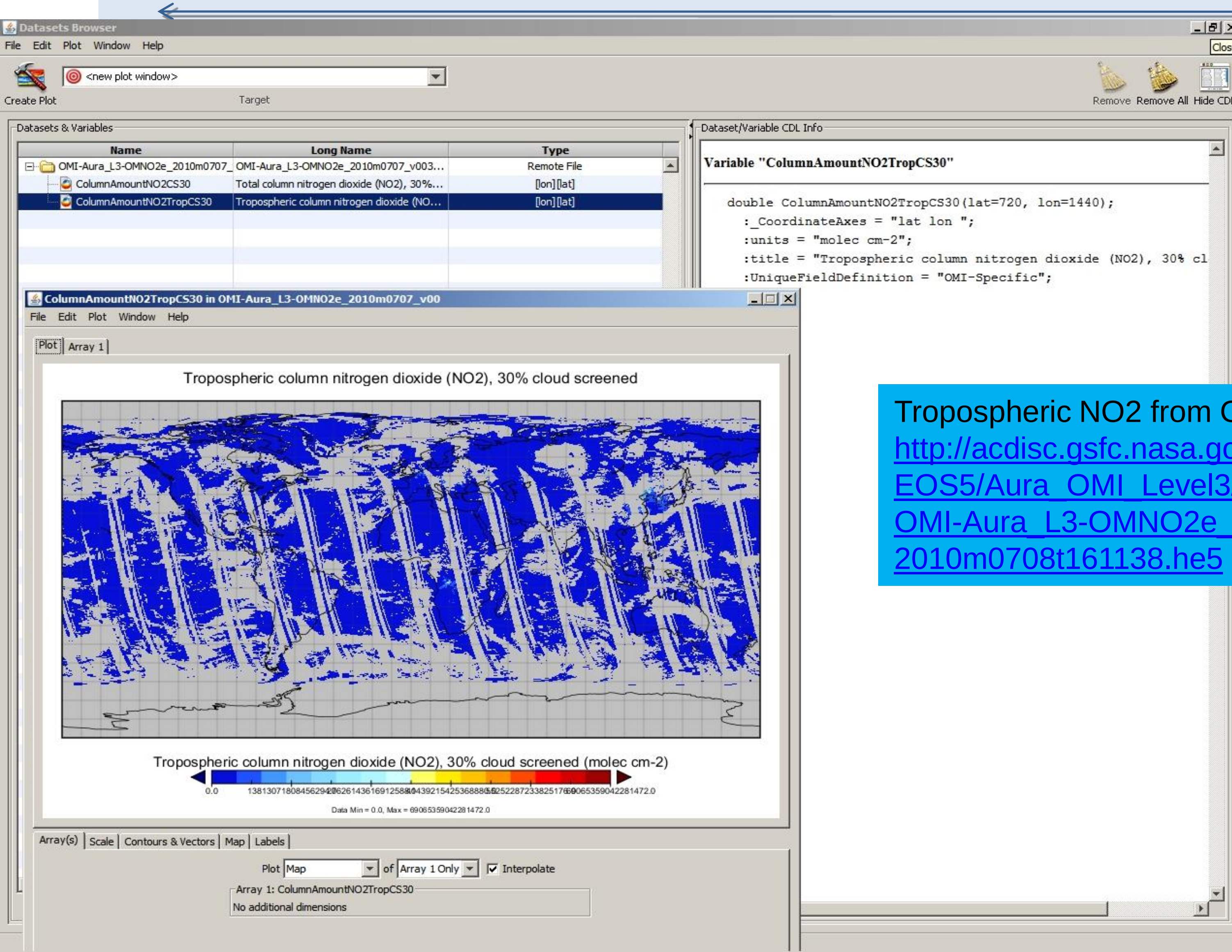
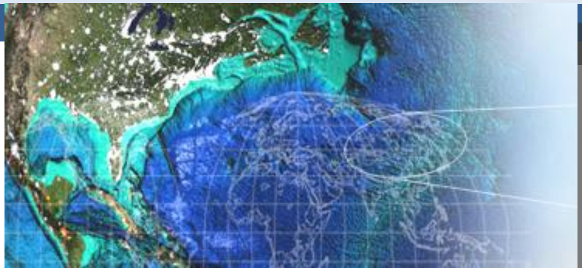
Panoply Example



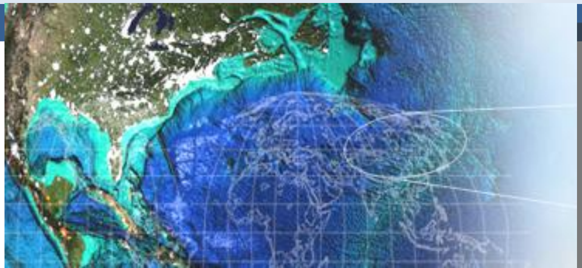
Tropospheric NO2 from OMI for July 7, 2010: http://acdisc.gsfc.nasa.gov/opendap/HDF-EOS5/Aura_OMI_Level3/OMNO2e.003//2010/OMI-Aura_L3-OMNO2e_2010m0707_v003-2010m0708t161138.he5

Other Examples

- Additional examples for Panoply and IDV, as well as examples for GrADS can be found at: http://wiki.esipfed.org/index.php/Making_Science_Data_Easier_to_Use_with_OPeNDAP
- This site also provides links to related tools.



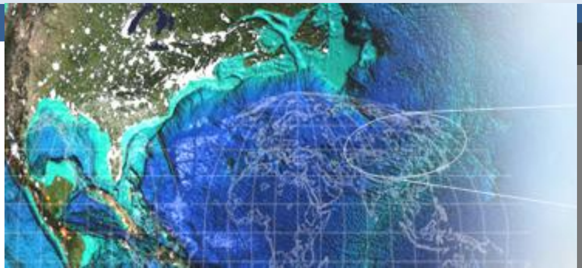
Catalog Search and Discovery



Catalog Services – Web (CS-W)

According to OGC specification, catalog services support the ability to publish and search:

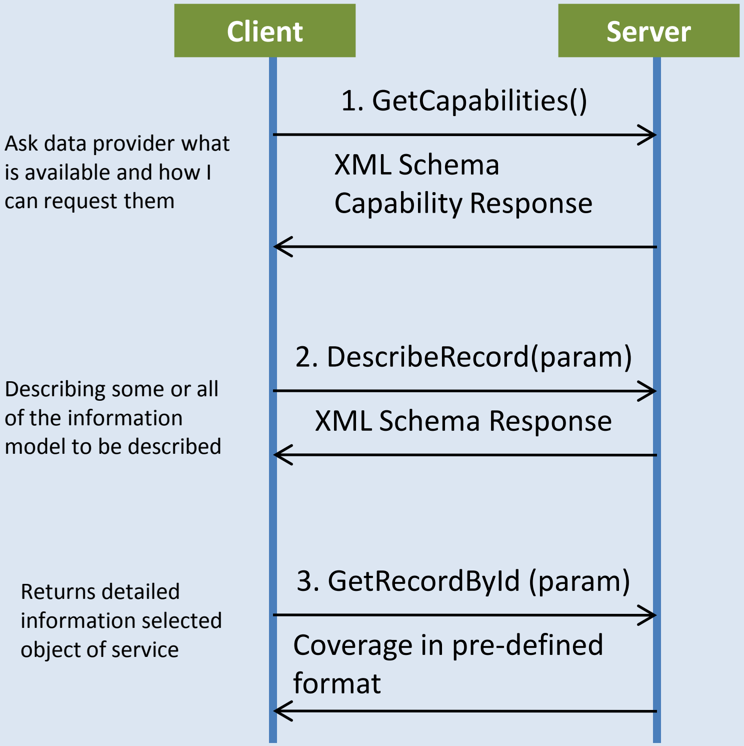
- Collections of metadata (representing resource characteristics)
- Catalog services (required to support the discovery and binding to registered information resources)
- Other related information objects

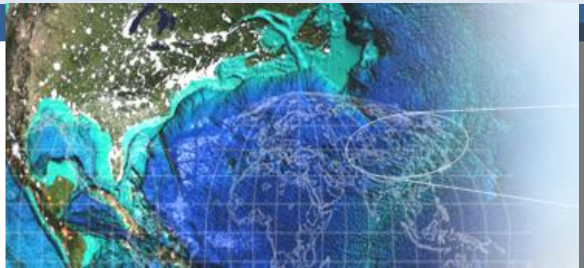


CS-W Abilities

CS-W Features

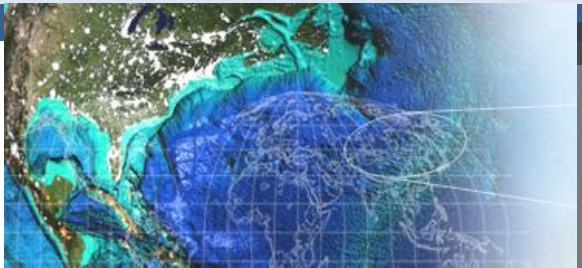
- **Provides four main Requests:**
  - GetCapabilities: Allows CS-W clients to retrieve service metadata from a server
  - DescribeRecord: Allows a client to discover all data model supported by the catalogue service
  - GetRecordById: Retrieves the default representation of catalogue records using their identifier.
  - GetRecords: Allows record filtering using a single filter element that can contain a potentially complex filter expression





OpenSearch

- OpenSearch is a collection of simple format for sharing of search results
- OpenSerach formats allows clients to discover and use your search engine
- Allows search engines and search clients to communicate using the common set of formats
- Was developed and created by Amazon.com and A9.com

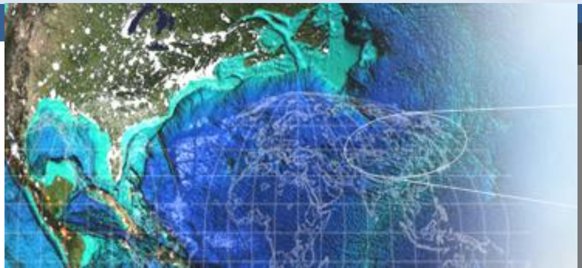


How to Use OpenSearch

- OpenSearch allows you to direct clients to your search engine or use your search engine.
- To direct clients to your web site:
  - Write a simple OpenSearch Description document to describe your search. See OpenSearch description XML document example in this link:

    http://www.opensearch.org/Specifications/OpenSearch/1.1#OpenSearch_description_document
- If you wish clients to use your search engine:
  - Syndicate your search results by formatting them with extended existing syndication formats, such as RSS or Atom formats, augmented with OpenSearch elements. See example provided in this link:

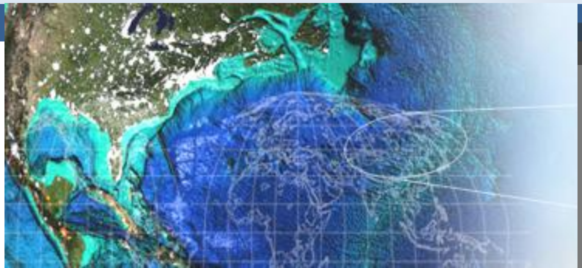
    http://www.opensearch.org/Specifications/OpenSearch/1.1#OpenSearch_response_elements



OpenSearch Clients

OpenSearch search clients include:

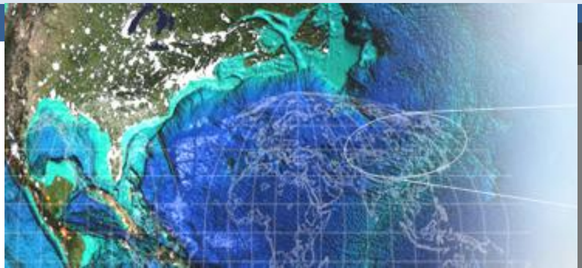
- Search Aggregator Websites
  - A9.com
  - OSfeed
  - TagJag
  - Keywop
- Web browsers
  - Internet Explorer 7: user instructions to install an opensearch provider- also supports OpenSearch Referrer Extension
  - Firefox 2.0 - also support OpenSearch Suggestions Extension
  - Arora - also supports OpenSearch Suggestions Extension and OpenSearch Referrer Extension
  - Google Chrome



Writing OpenSearch (1/2)

Writing OpenSearch results with various types of software

- Alfresco
- Drupal OpenSearch Results by Robert Douglass
- Kwiki by Tatsuhiko Miyagawa
- Lucene
- Lucene by Apache.org
- Nutch
- PyOpenSearch example Python Whoosh application with jQuery client



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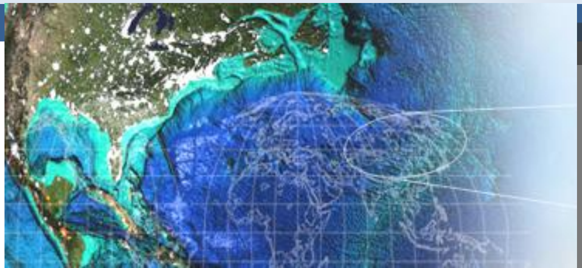
Writing OpenSearch (2/2)

Additional types of software for writing OpenSearch

- OpenLink Data Spaces by OpenLink Software
- MediaWiki by Gregory Szorc
- Moveable Type by Alf Eaton
- PLOS (Plone OpenSearch)
- SearchGenerator (Ruby on Rails)
- Wordpress by Chris Fairbanks
- GeoNetwork opensource geospatial catalog



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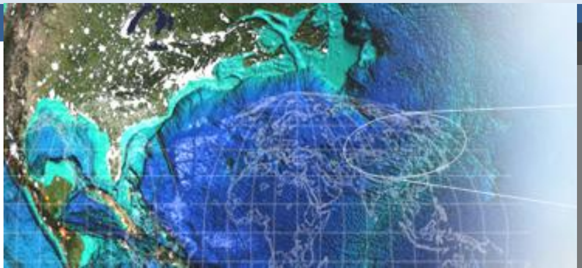
Reading OpenSearch Description Documents

Reading OpenSearch

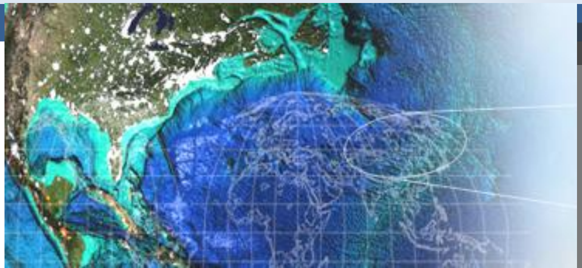
- Drupal client library by Robert Douglass
- Drupal OpenSearch Aggregator by Steven Wittens
- Perl library by Tatsuhiko Miyagawa and Brian Cassidy
- PHP Hirose Masaaki
- Python library by Ed Summers
- ROME plugin
- OpenLink Virtuoso by OpenLink Software
- Apache Abdera
- OJAX
- LibraryFind open source metasearch application
- qopensearch - a set of Qt classes



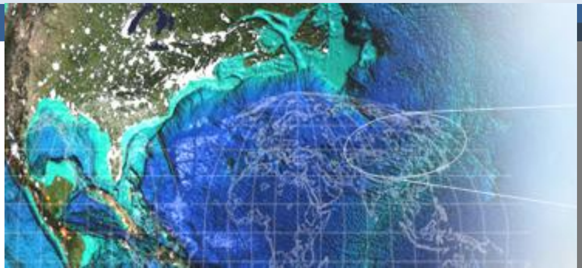
ESIP Federation OpenSearch

The ESIP Federation Open Search utilizes OpenSearch description XML document for Two Step Search:

1) Search for datasets and then granules within the selected dataset
2) Space-time granule query for the selected dataset

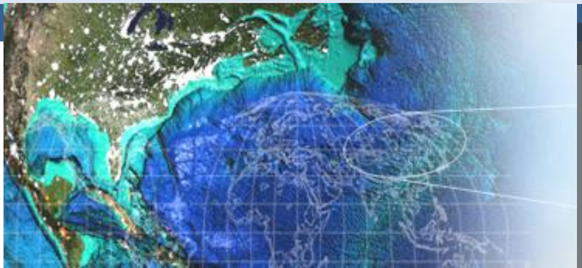


Usage and File Formats



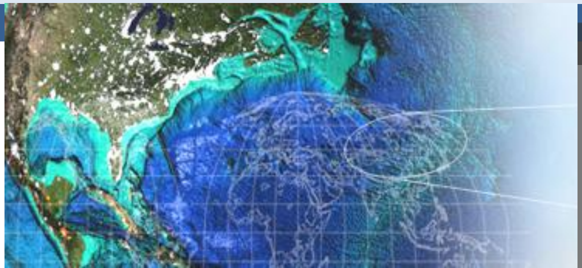
Metadata and Related Standards (1/2)

- Federal Geographic Data Committee (FDGC) Metadata standards
  - FGDC Content Standard for Digital Geospatial Metadata (CSDGM) and its extension of remote sensing data to design and implement catalogue service.
- NetCDF refers to a data model for array-oriented scientific data.
- Climate and Forecast (CF) conventions for netCDF serve as a interoperability standard.



Metadata and Related Standards (2/2)

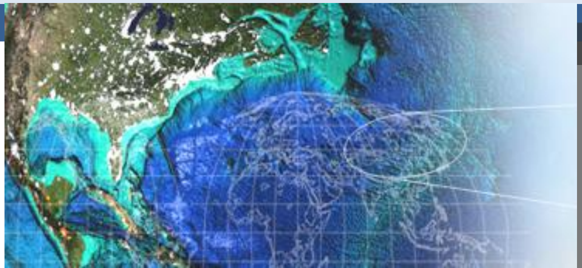
- Geospatial datasets (ISO 19115 parts I and II metadata)
- Geospatial services (ISO 19119)
- NASA ECS (EOS Core System) and remote sensing datasets
- NASA Global Change Master Directory (GCMD) DIF (Directory Interchange Format) see: http://gcmd.nasa.gov/User/difguide/difman.html



FGDC Metadata Standard

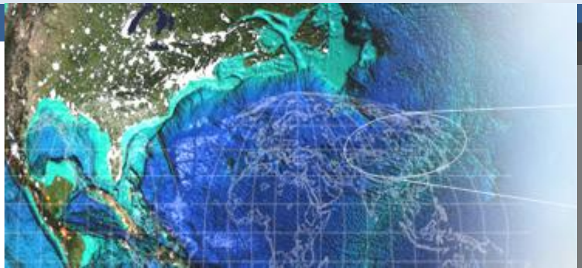
The Content Standard for Digital Geospatial Metadata (CSDGM), Vers. 2 (FGDC-STD-001-1998) is the current US Federal Metadata standard. The FGDC originally adopted the CSDGM in 1994 and revised it in 1998. According to Executive Order 12096, all Federal agencies are ordered to use this standard to document geospatial data created as of January 1995. The standard is often referred to as the 'FGDC Metadata Standard' and has been implemented beyond the federal level with State and local governments adopting the metadata standard as well.

http://www.fgdc.gov/metadata/geospatial-metadata-standards



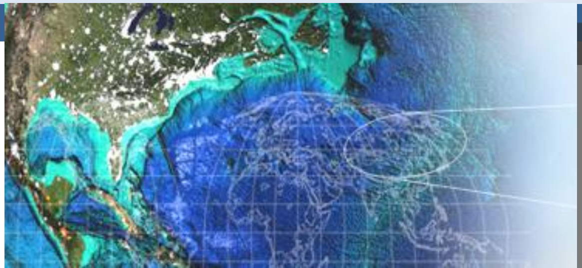
FGDC Content Standard for Digital Geospatial Metadata (CSDGM)

"The objectives of the standard are to provide a common set of terminology and definitions for the documentation of digital geospatial data. The standard establishes the names of data elements and compound elements (groups of data elements) to be used for these purposes, the definitions of these compound elements and data elements, and information about the values that are to be provided for the data elements."



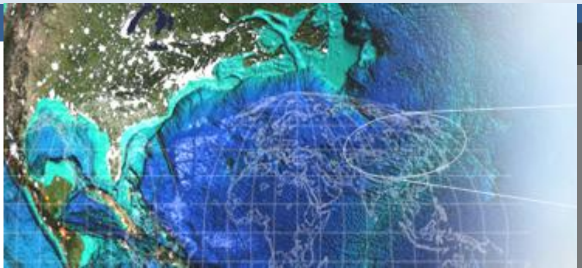
NetCDF

- “NetCDF (network Common Data Form) is a set of software libraries and machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data.”
- Downloads are available at http://www.unidata.ucar.edu/downloads/index.jsp



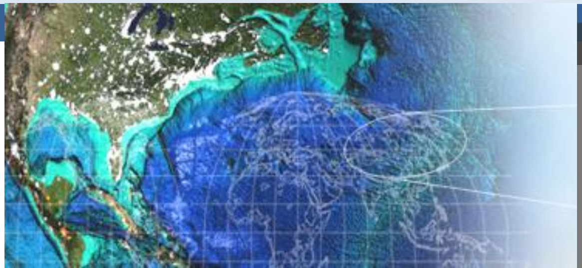
Climate and Forecast (CF) Metadata

- “The conventions for climate and forecast (CF) metadata are designed to promote the processing and sharing of files created with the NetCDF API.”
- “The conventions define metadata that provide a definitive description of what the data in each variable represents, and the spatial and temporal properties of the data.”
- “This enables users of data from different sources to decide which quantities are comparable, and facilitates building applications with powerful extraction, regridding, and display capabilities.”



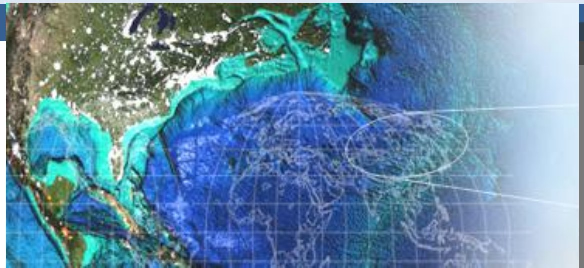
Geospatial datasets (ISO 19115 part I and II metadata)

- ISO 19115:2003 defines the schema required for describing geographic information and services. It provides information about the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data.
- This is revised by ISO 19115-2:2009 (Extensions for imagery and gridded data) and ISO/NP 19115-1, which is currently in development with a target publication date around mid-2012.



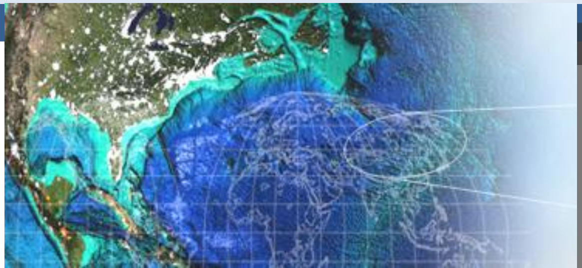
Geospatial services (ISO 19119)

ISO 19119:2005 identifies and defines the architecture patterns for service interfaces used for geographic information, defines its relationship to the Open Systems Environment model, presents a geographic services taxonomy and a list of example geographic services placed in the services taxonomy. It also prescribes how to create a platform-neutral service specification, how to derive conformant platform-specific service specifications, and provides guidelines for the selection and specification of geographic services from both platform-neutral and platform-specific perspectives.



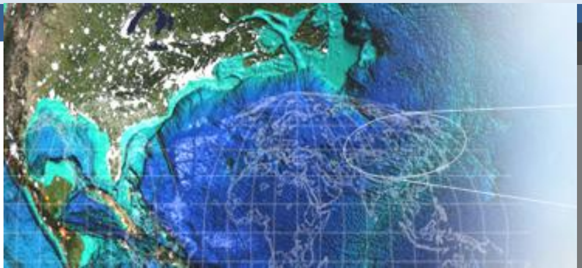
NASA GCMD DIF (Directory Interchange Format)

- Originated in 1987 as the product of an Earth Science and Applications Data Systems workshop, as a step towards data system interoperability. GCMD DIF is a metadata file format.
- As the "container" for the metadata in the Committee on Earth Observation Satellites (CEOS) International Directory Network (IDN), it does not compete with other metadata standards.
- The metadata used by the GCMD is considered to be that set of attributes that are instrumental in helping users to determine if a data set meets their qualifications. The set of attributes (fields) and its associated syntax is known as the Directory Interchange Format (DIF). It has evolved over the years and serves the user community in the discovery of Earth science data.

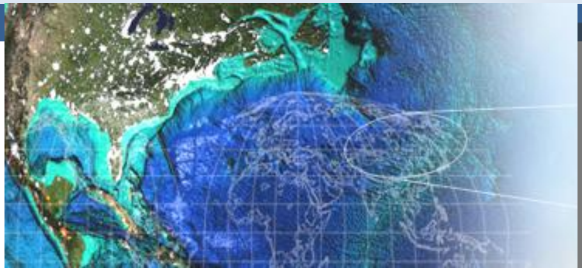


Relational Database Management System (RDBMS)

A **relational database management system (RDBMS)** is a database management system (DBMS) that is based on the relational model as introduced by E.F. Codd. Most popular commercial and open source databases currently in use are based on the relational database model.

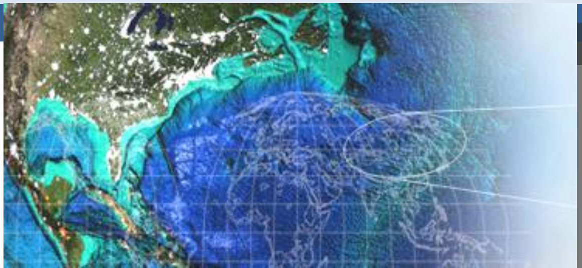


Semantic Web



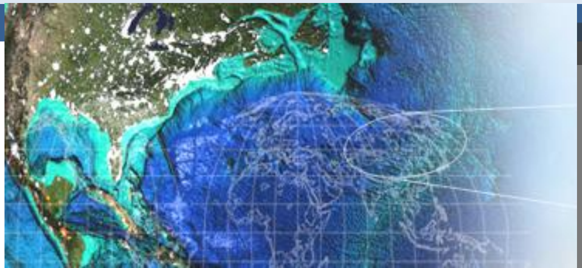
Semantics

Semantics (from Greek sēmantikós) is the study of meaning. It typically focuses on the relation between signifiers, such as words, phrases, signs and symbols, and what they stand for.



Semantic Web

- Semantic Web was coined by Tim Berners-Lee the inventor of WWW, HTTP, URLs, HTML and director of the World Wide Web Consortium (W3C)
- The Semantic Web is an extension of the World Wide Web through the embedding of additional semantic metadata, using semantic data modeling techniques such as Resource Description Framework (RDF) and OWL Web Ontology Language (OWL).



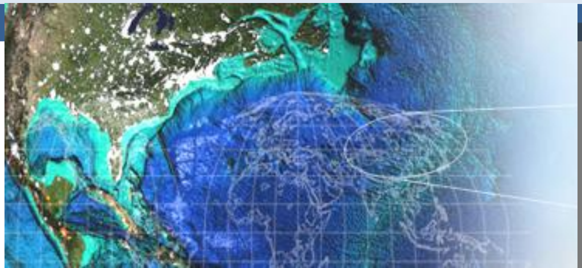
Syntactic Web vs. Semantic Web

Syntactic Web

- Interchange data is controlled by application
- Interpretation and identification of the data are done by human beings
- With the increase in volume of data and complexity, it is virtually impossible to manage the data (Information Overload)
- Information Overload can pose a serious threat to Syntactic usefulness.

Semantic Web

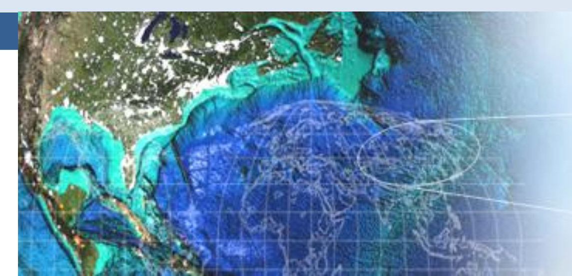
- Utilizes common formats of data and combines them together from different sources
- Provides capabilities to record how data are related to real world objects
- Allows humans or machines to start searching one database and move on to an unending set of databases
- Databases are not connected via wires, but by the same concepts.



Semantic Web Example

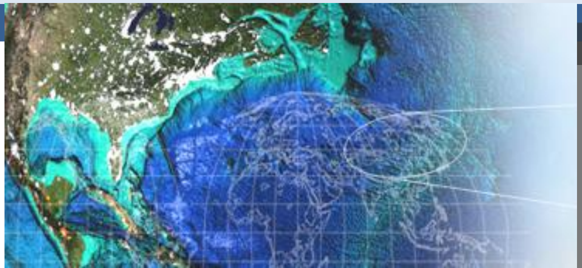
Purchasing a new computer

- Search criteria are: 17-inch screen, 4 GB of RAM, bonus software and games, lowest available price, new, free shipping or shipping cost less than $10
- With Syntactic Web all you can do is search through different web pages and compare the conditions listed above, or use pages that compare dealers with available prices
- With a Semantic Web Agent:
  - User enters preferences listed above into computerized agent
  - Agent will initiate a complex search through invisible metadata only visible to computers.
  - Agent will display the best option, let you place an order, open your credit card payments, and mark the date of arrival



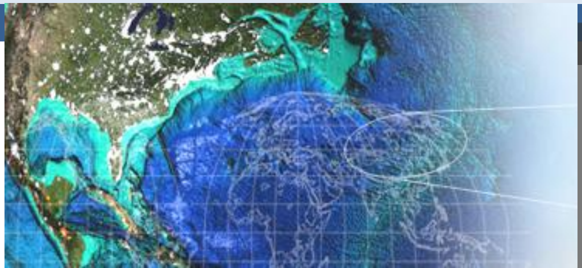
Geospatial Semantic Web (GSW)

- The idea behind GSW is to have "discovery, query, and consumption of geospatial content … based on formal semantic specification."
- An OGC Interoperability Experiment which "aims to augment WFS/FE with a semantic query capability, through the definition of an ontology for the geospatial intelligence community."



GSW Interoperability

The GSW will enable the meaning of geographic queries to be easily shared among different software systems and online services.



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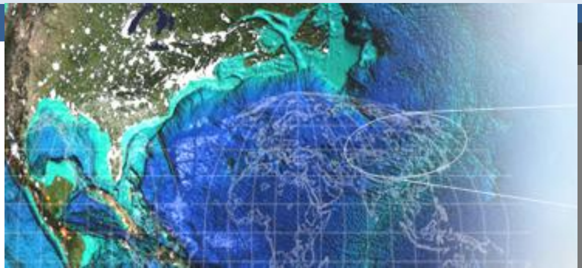
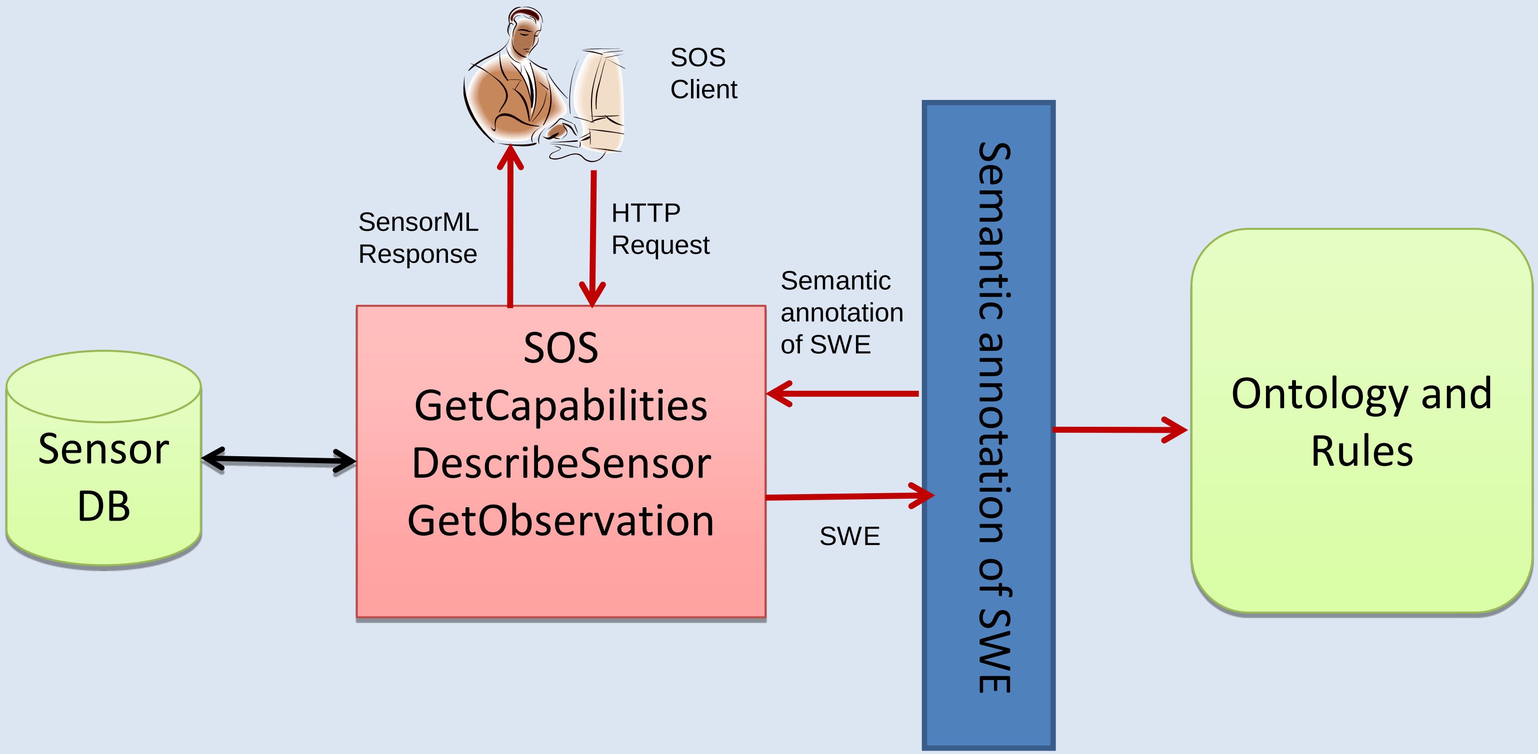
Semantic Sensor Web (SSW)

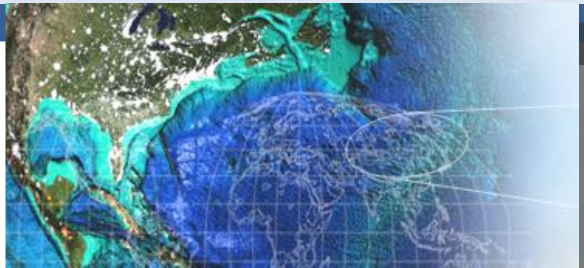
The SSW is a framework for providing enhanced meaning for sensor observations by adding semantic annotation to existing SWE to:

- Provide more meaningful descriptions
- Provide more access to sensor data
- Provide a mechanism to bridge the gap between syntactic XML-base metadata standards of SWE and Resource Description Framework (RDF) and Web Ontology Language (OWL) based metadata standards of Semantic Web

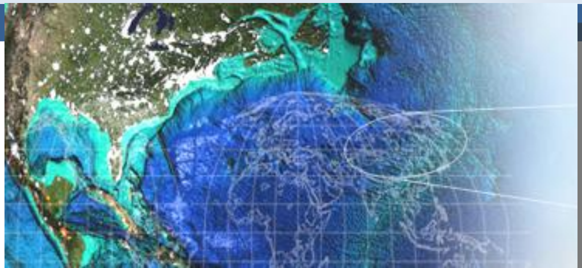


SOS and SWE Architecture Using SSW Technology



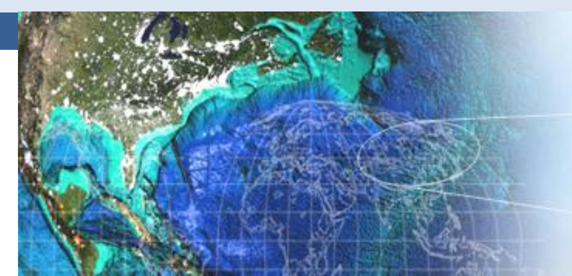


Case Studies



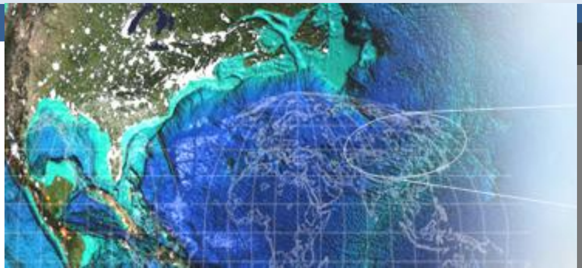
Case Studies

- Case studies illustrate the benefits of using interoperability standards.
- The following case studies are presented:
  - MODIS Adaptive Processing Systems (MODAPS) WCS Web Services
  - The NOAA-led Integrated Ocean Observing System (IOOS)
  - NASA’s sensor webs



MODIS Adaptive Processing System (MODAPS) WCS Web Services (1/3)

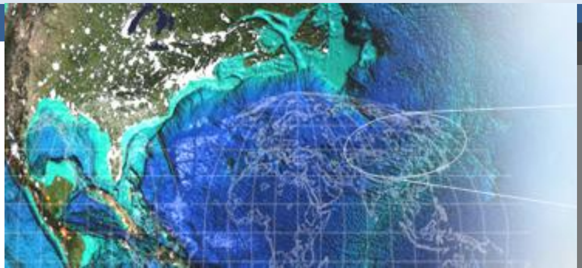
- Provides a SOA machine-to-machine API to level 1 and atmospheric archived MODIS (Moderate Resolution Imaging Spectroradiometer) data
- Utilizes standard Web Service interfaces through both Simple Object Access Protocol (SOAP) and Representational State Transfer (REST) protocols
- Allows OpenSearch and the Open Geospatial Consortium's Web Coverage Service (WCS) interfaces



MODAPS WCS Web Services (2/3)

Provide synchronous web services that allows users to utilize WCS capabilities to perform:

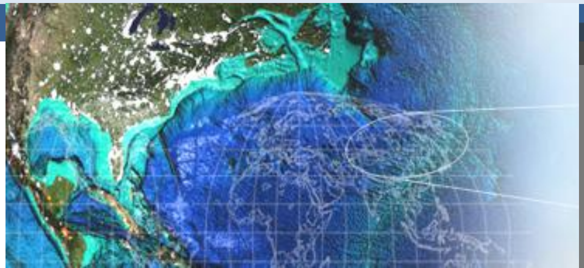
- Exchange of information with OpenSearch and Open Geospatial Consortium
- Gridded search
- Post processing



MODAPS WCS Web Services (3/3)

MODAPS WCS Web Services Implementation Issues and Concerns

- WCS Issues and Concerns
  - Implementation issues using AXIS2
  - MODAPS data volume and WCS capability
  - WCS Schema validation and Java binding dilemma
- Our Approach
  - Considering other Web Services Framework
  - Using automated schema binding technologies



MODAPS WCS Web Services – Issues and Concerns

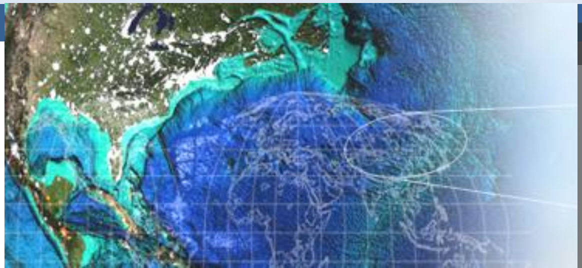
SOA and AXIS2

- Security
- AXIS2 Software Support
- Contract last vs. Contract first

MODAPS WCS Web Services – WCS Schema Issues

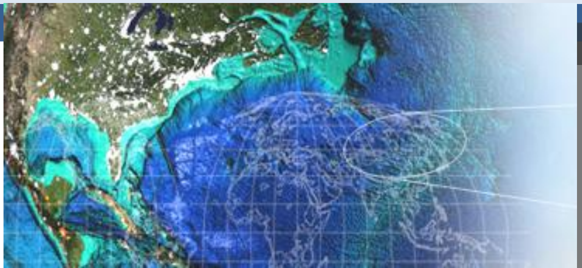
OGC WCS Schema

- WCS Schema fails to support MODAPS's large number of products
- XMLSpy fails to validate OGC WCS Schema version 1.0.0
- Castor binding tools fail to create Java classes to support this Schema
- WCS Schema many based objects which are restricted
  - This schema design causes failures within Castor binding



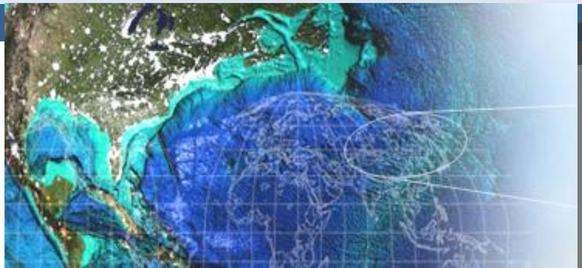
MODAPS WCS Web Services – Lessons Learned

- Use experience with other technologies such as Spring Web Services instead of AXIS2 to eliminate:
  - Dependencies to AXIS2 OMElement
  - AXIS2 Security issues
  - AXIS2 lack of software and security support
- Use XML binding COTS products such as Castor to eliminate manual implementation of Java API to handle OGC WCS Schema.
- Difficulty with validating WCS Schema, modifying the schema to be readable by the Castor binding tool, and at the same time protect the integrity of WCS Schema standards.

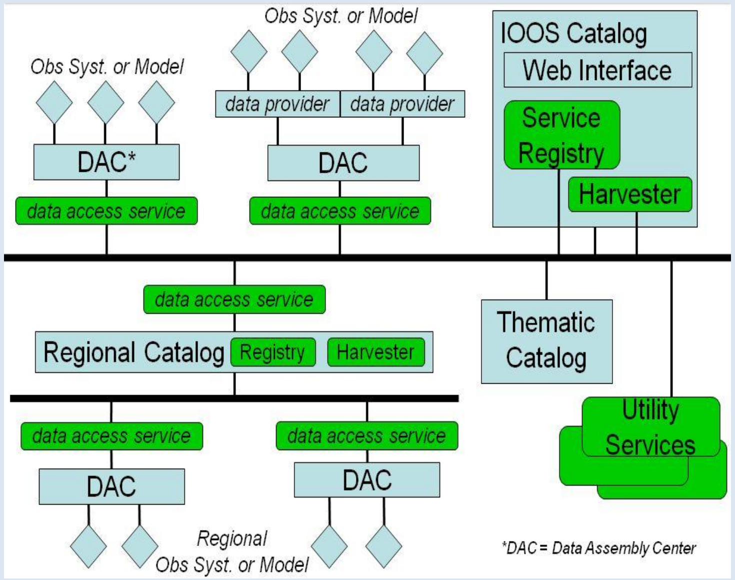


The NOAA-led Integrated Ocean Observing System (IOOS)

- The Integrated Ocean Observing System (IOOS) is a coordinated network of people and technology that work together to generate and disseminate continuous data on our coastal waters, Great Lakes, and oceans.
- "By collecting and bringing data together in a way that ensures the information can be used with other data sets, IOOS will make a broader suite of data available to scientists, allowing them to develop a more complete characterization of our oceans and coasts."
- "IOOS is a major shift in our approach to ocean observing, drawing together many networks of disparate, Federal and non-Federal observing systems to produce data, information, and products at the scales needed to support decision making."



About IOOS

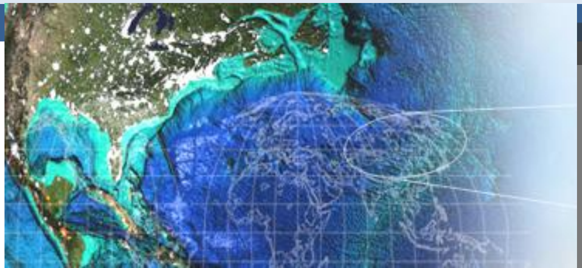


This figure shows an IOOS federated, service-oriented architecture.

- The Integrated Ocean Observing System (IOOS) provides information about open oceans and US coastal waters and Great Lakes to scientists, managers, businesses, governments, and the public in order to support research, to inform decision-making, and to enable new applications and derived products beyond the original intent of the data gathering. The US National Oceanic and Atmospheric Administration (NOAA) has been assigned the role of lead federal agency in this endeavor.
- Technically, IOOS includes or interfaces with existing observing systems, data providers, and archives, and IOOS collaborates in developing additional capabilities in observations, data management and data use.
- The IOOS uses mostly OGC Sensor Observation Service (SOS) and Unidata's Data Access Protocol (DAP), and to a somewhat lesser extent (so far) OGC Web Coverage Service (WCS) and Web Map Service (WMS).

IOOS Data Access

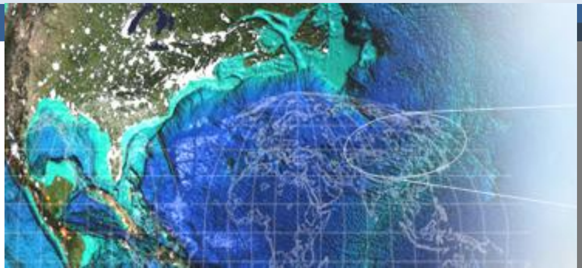
- The NOAA IOOS program initiated development of a Data Integration Framework (DIF) to improve management and delivery of an initial subset of ocean observations.
- The following services are the first to be established by the NOAA IOOS program and its partners to provide access to data:
  - National Data Buoy Center (NDBC) Sensor Observation Service (SOS)
  - CO-OPS SOS
  - NDBC THREDDS Data Server
  - SECOORA SOS



Sample National Data Buoy Center SOS Output

- GetObservation for WaterLevel (sea_floor_depth_below_sea_surface)
- Single point, Station 46403, observation for a specific time, CSV format
- http://sdf.ndbc.noaa.gov/sos/server.php?request=GetObservation&service=SOS&offering=urn:ioos:station:wmo:46403&observedproperty=sea_floor_depth_below_sea_surface&responseformat=text/csv&eventtime=2008-07-17T00:00Z

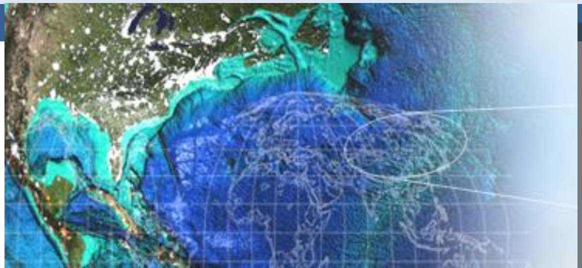
```
station_id,sensor_id,"latitude (degree)","longitude (degree)",date_time,"sea_floor_depth_below_sea_surface (m)","averaging interval (s)"
urn:ioos:station:wmo:46403,urn:ioos:sensor:wmo:46403::tsunameter0,52.65,-156.94,2008-07-17T00:00:00Z,4509.488,900
```



Sample CO-OPS SOS Output

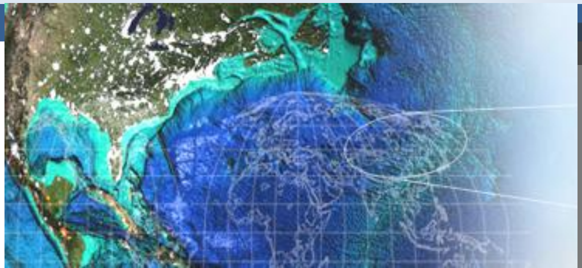
- Currents Data (GetObservation Service)
- Profile Bin Data (Latest), Station db0301
- Result format text/xml


```
…
<ioos:Count name="Station1T1NumberOfBinObservations">40</ioos:Count>
<ioos:ValueArray name="Station1T1ProfileObservations" gml:id="S1T1PO">
   <gml:valueComponents>
     <ioos:CompositeValue name="Station1T1Bin1Obs" gml:id="S1T1B1" processDef="#Station1Sensor1Info">
       <gml:valueComponents>
         <ioos:Quantity name="CurrentDirection" uom="deg">199.0</ioos:Quantity>
         <ioos:Quantity name="CurrentSpeed" uom="cm/s">39.1</ioos:Quantity>
       </gml:valueComponents>
     </ioos:CompositeValue>
…
```

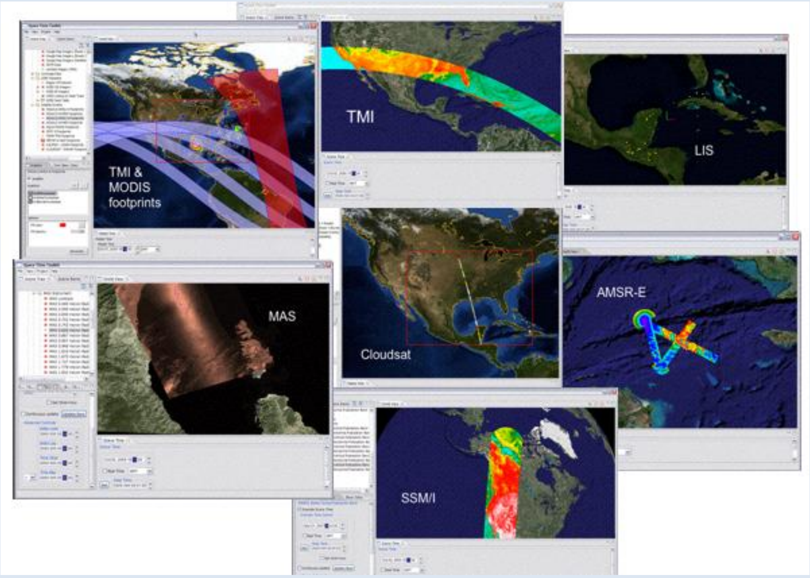



IOOS Software

- The IOOS also provides some software on an “as-is basis with no support or warranty”, including
- Server Code
  - NDBC SOS software version 1
  - GCOOS SOS software beta version 0.6.1
  - THREDDS Data Server (TDS)
- Format Converters
  - IOOS SOS to CSV v0.6.1
  - netCDF to BUFR converter beta v0.1

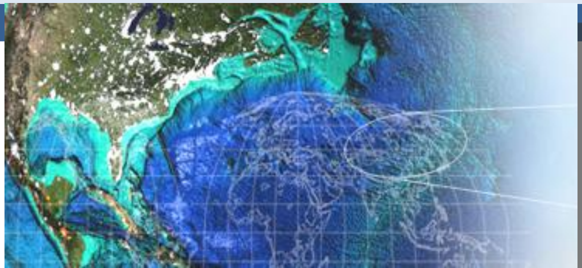


NASA's Sensor Webs (1/4)

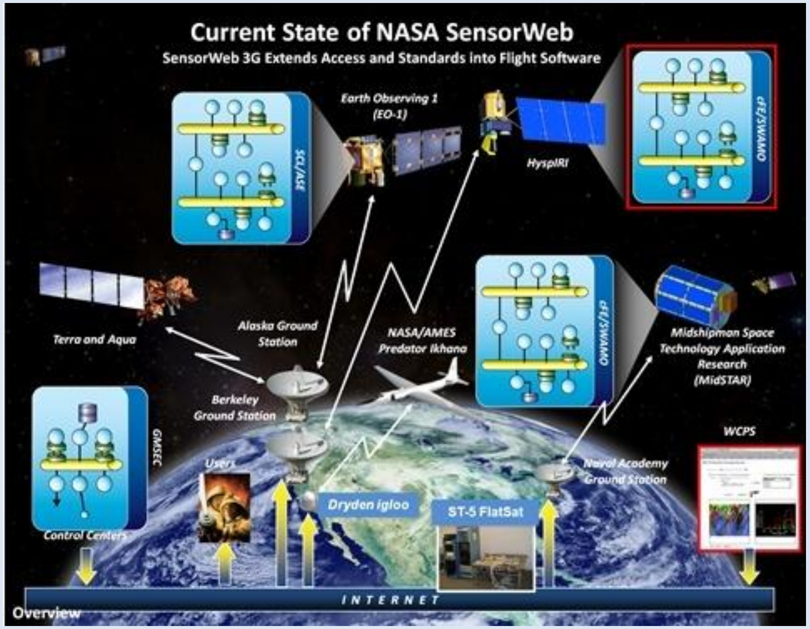


All of these satellite and airborne sensors are, at least some of the time, using SensorML for geolocation and other purposes. See NASA's JPL and GSFC Sensorweb/EO-1 pages.

- A number of NASA projects have adopted the OGC SWE suite of standards.
- Collaboration between JPL and GSFC with the Earth Observing 1 (EO-1) satellite is an important part.
- EO-1 was used in a wildfire sensor web scenario, and GSFC with partners prototyped a transformation to an SWE framework using GeoBliki



NASA's Sensor Webs (2/4)



- "The main objective of the sensorweb activity is to create an interoperable environment for a diverse set of satellite sensors via the use of software and the Internet … to better understand physical phenomena … [and] it facilitates science investigation."
- "The end goal is to make discovery and access to sensors as easy as finding and using websites on the Internet."

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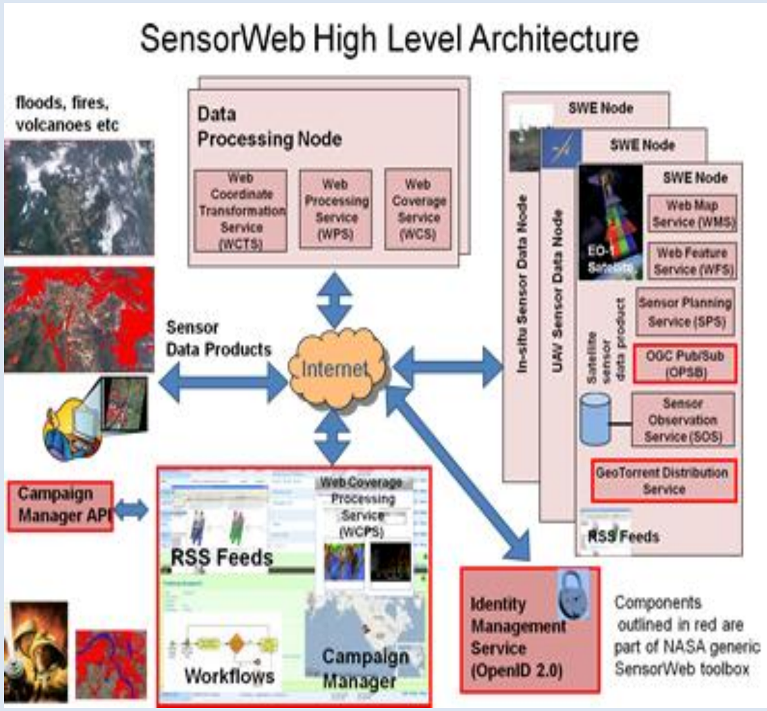
NASA's Sensor Webs (3/4)



- The basic components are:
  - Reference architecture
  - A set of web services
  - Cross-domain generic scripting language
  - Campaign Manager 1.0
  - Campaign Manager 1.0 API
  - Identity Management Service
  - OGC Publish/Subscribe
  - GeoTorrent
- The five components outlined in red in the figure at left were created by NASA to augment the international standards.

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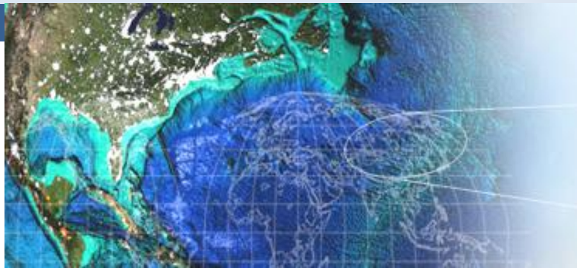
NASA's Sensor Webs (4/4)

- Nearly 100 papers, over 30 presentations, and 16 articles on NASA's sensor web efforts are listed at http://eo1.gsfc.nasa.gov/new/sensorWebExp/Papers.html
- Subject areas include:
  - An interoperable sensor architecture
  - Autonomous sciencecraft experiments
  - On-board diagnostics tools
  - Adaptive phased array ground antennas

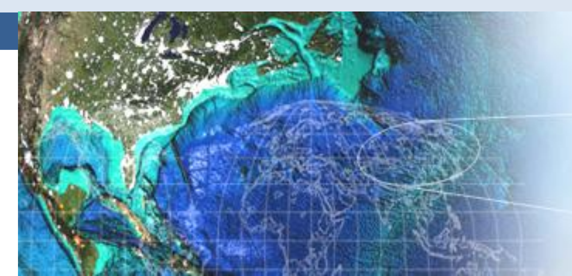


Additional Resources

A document on Practical Data Interoperability for Earth Sciences is available at http://www.esdswg.org/techinfusion/downloads/pdies

OpenGIS

- Members of the OGC have developed OpenGIS specifications for SQL, CORBA, and OLE/COM.
- These form the basis of the "Spatial Web" in that just as web sites implement HTML, sites serving spatial data or processing services will need to implement OpenGIS specifications in order to be part of the open spatial web.



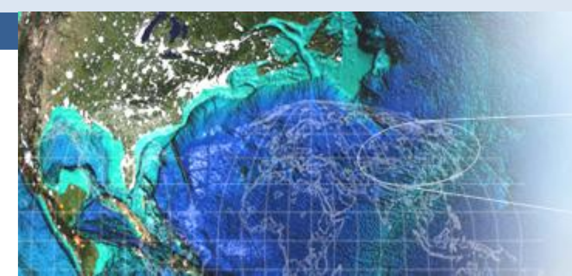
OpenGIS Standards

Some OGC OpenGIS standards have been discussed already:

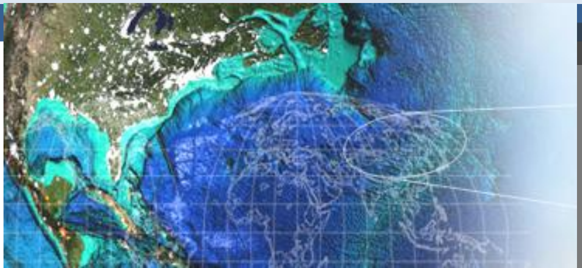
- WMS
- WFS
- WCS
- C-SW
- SensorML

Other OpenGIS standards include:

- GeoXACML
- OGC KML
- OpenGIS CityGML
- OpenGIS Location Service



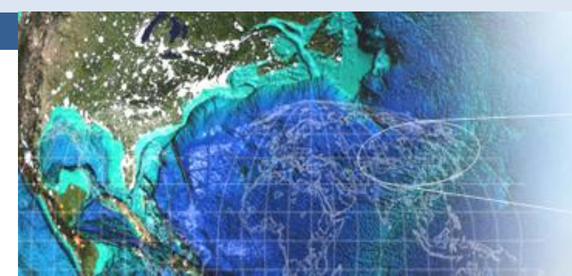
Computing Platforms



Computing Platforms

The essential keys of meeting the complex challenges of sharing information among multiple sources are the abilities to:

- Discover data
- Access data
- Integrate data
- Share information effectively



What are the Driving Factors?

Internet
- Interoperable Web Services
- Client Interface

Wireless Tools
- Thin Clients with limited bandwidth

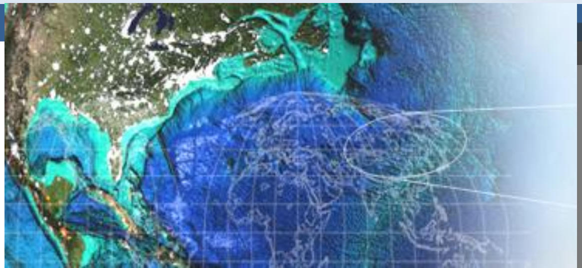
Spatial Data
- Satellite imagery/data
- Variety of data providers

Standards Roles
- Integration of Enterprise's databases/Components

Infrastructure for Automated Distributed Computing Services

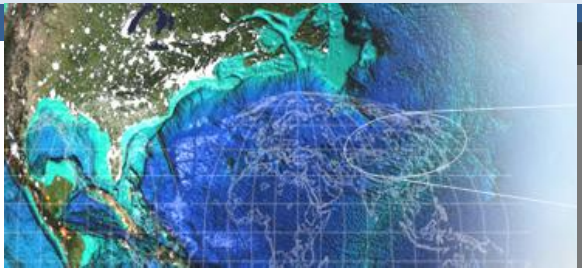
Frameworks

- Web Services
- SOA
- Distributed Objects



Web Services

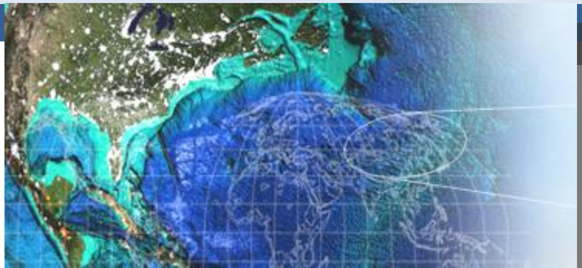
- Web services represent a new architecture for creating applications that can be accessed from a different system.
- Web Services are self-describing, modular applications that can be published, located, and invoked dynamically over the web.
- Enables interoperability across:
  - Distributed computing platforms
  - Operating systems
  - Programming languages
  - Geographic boundaries



Web Services Framework

Web Services Framework:

- Enables interoperable services over the standard interfaces
- Supports publishing, discovery, and binding services
- Separates data instances from service instances
- Enables one provider's services to be used by another provider's data



Web Services Core Standards (1/3)

Web Services Core Standards:

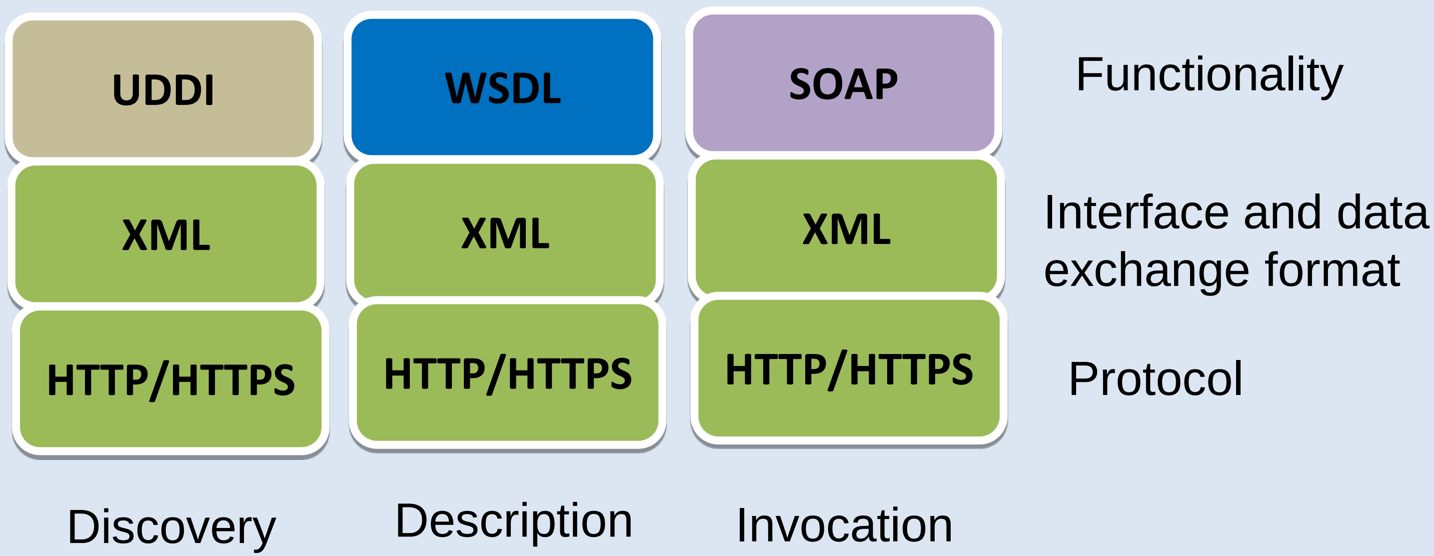
- HTTP
- HTTPS
- SOAP
- XML
- XML Schema
- WSDL
- UDDI

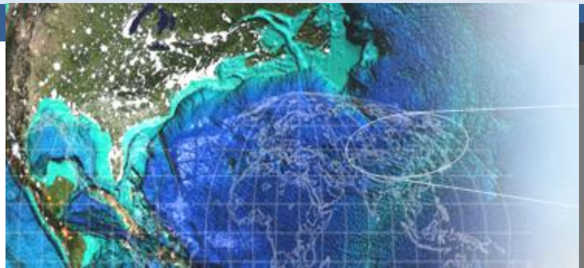
Web Services Core Standards (2/3)

Web Services builds on five key protocols: HTTP, XML, UDDI, WSDL, and SOAP

- HTTP and HTTPS are transport protocols.
- XML is a standard data format for implementing service interface and data exchange formats.
- UDDI, WSDL, and SOAP are used for discovering, describing, and invoking data, respectively.

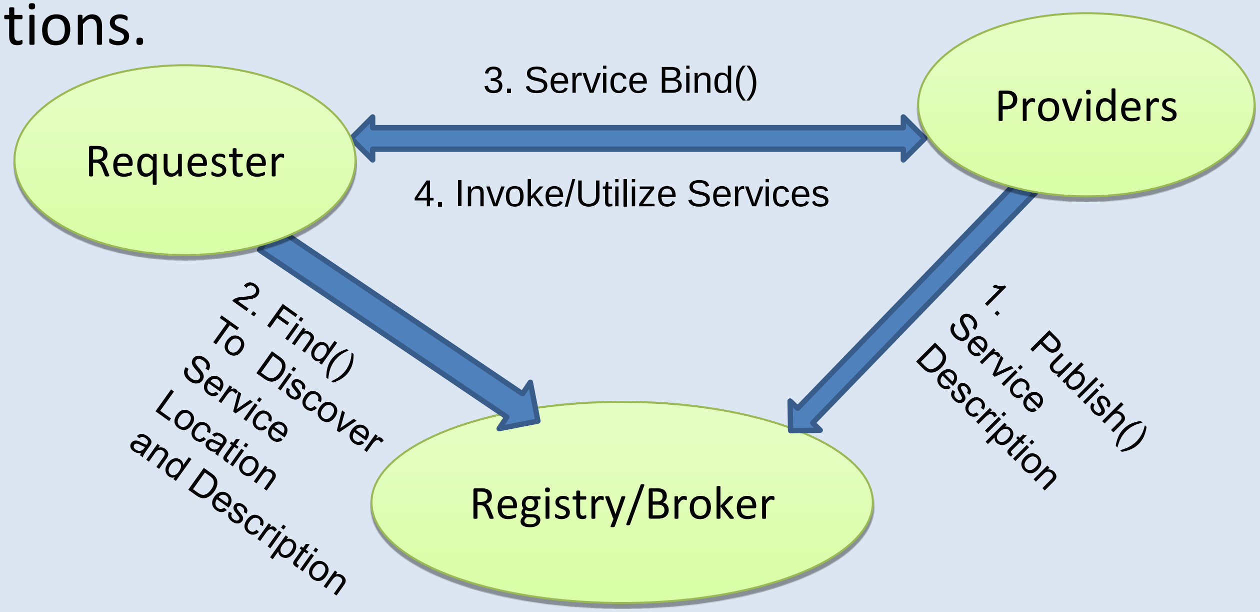
Web Services Core Standards (3/3)





Service Oriented Architecture (SOA)

- The SOA provides a theoretical model for all Web Services.
- The SOA model contains three entities and three operations.



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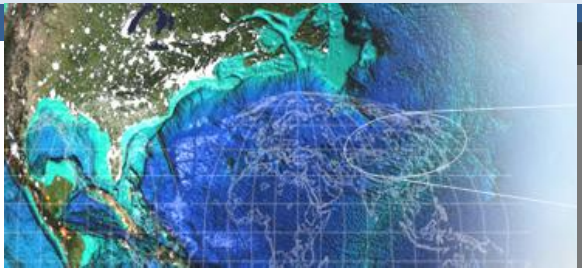
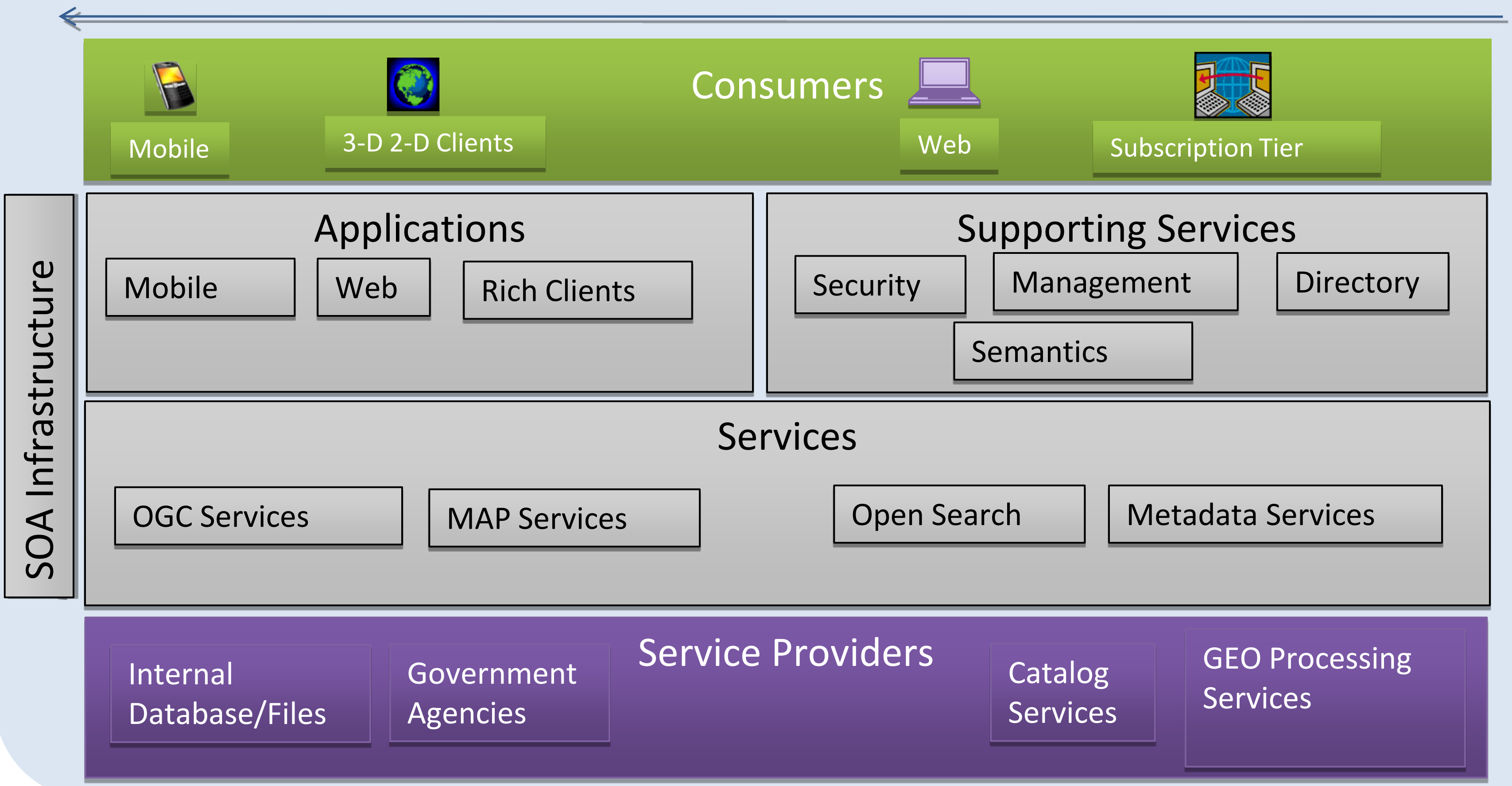
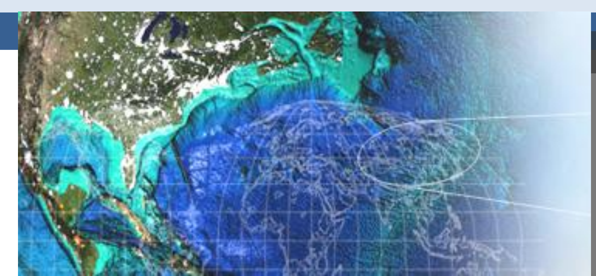
SOA Entities and operations

- The Service *Requester* is an application that is looking for services. To locate desired services, it turns to *Registry* and requests a Find() operation.
- The *Registry* is a well-known application that returns information regarding registers in response to search criteria submitted by Find() operations.
- The *Provider* Publish() these details as well as information about how to access provider and connection details.
- Requester uses connection details to Bind() to the Provider.



Geospatial SOA Infrastructure (1/2)





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Geospatial SOA Infrastructure (2/2)

SOA Infrastructure

Applications

Mobile
- -Mobile .NET
- -J2ME
- -PDA Apps

Web
- -.Net
- -J2EE
- -Spring

Rich Clients
- -Heavily and Light Client
- -Highly Interactive

Supporting Services

Security
- -LDAP
- -Certificate
- -WS Security

Semantics
- -OWL/RDF

Management
- -JMX

Directory
- -UDDI
- -OGC CS-W with ebXML

Services

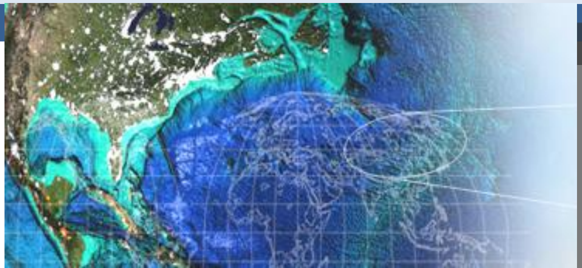
Database/Data Files
- -ODBC
- -JDBC
- -RPC
- -Geo DB

Data Access
- -WMS
- -WFS
- -WCS
- -SWE

Open Search
- -CS-W
- -Federated Open Search
- -ESIP Open Search

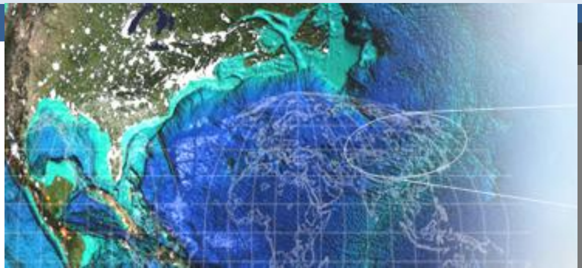
Metadata Services
- -FGDC
- -NetCDF

Geographic Information Services (GIS)
- -3D Globe Maps
- -GPS
- -Weather Data
- -Google Map
- -GIS Analysis
- -GIS Modeling and Projections



SOA vs. Distributed Objects

- SOA is opposite of the concept of distributed objects.
- With SOA:
  - Data are exchanged between different systems where each system operates on its own local copy.
  - Each system operates using its own local methods and procedure.
  - Each system is decoupled from others.
  - Not like distributed objects, each connected system has its own business object model. Therefore, the systems are allowed to scale.



Other Alternatives

- Remote procedure call architectures such as Java RMI, DCOM, and CORBA
- HTTP-like transactional architectures like Servlet/JSP, ASP, PHP, and CGI
- Screen Scraper client-side program. It uses the existing interface by pushing data into the interface, and then scrapes the returned data off the interface and converts them into something the client application needs.

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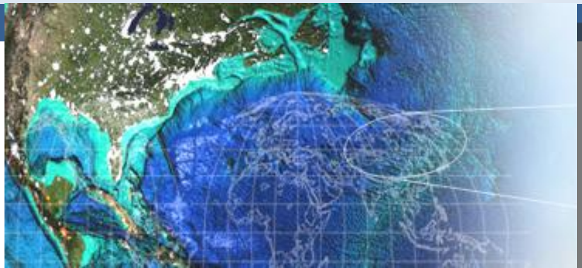

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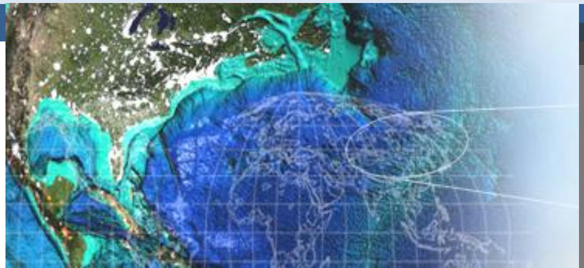

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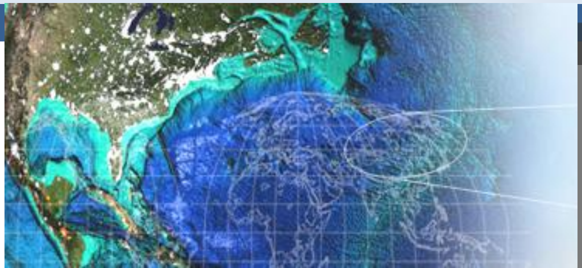

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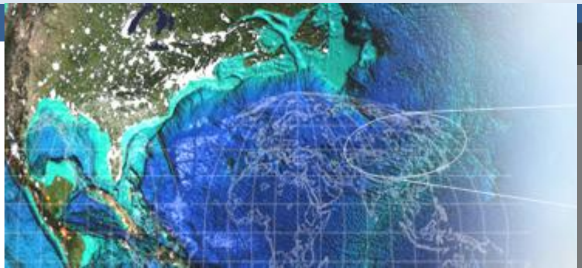

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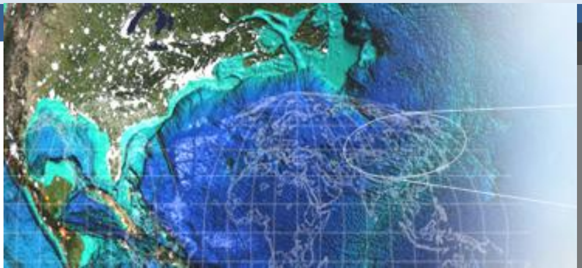

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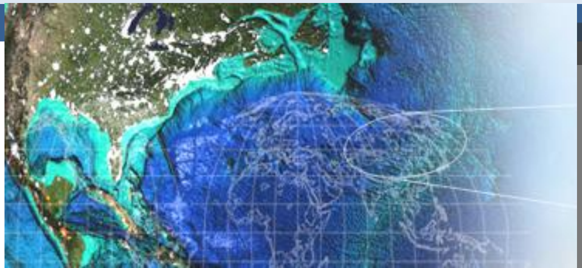

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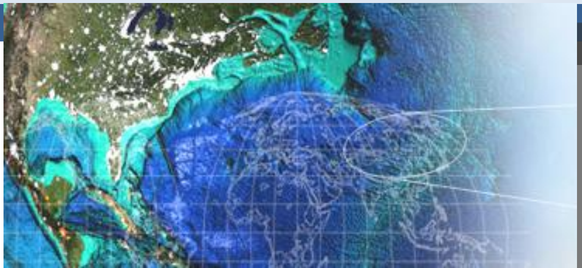

Thank you!